Draft Technical Report
Project Description
Appendices

Volume 2

WyCoalGas Coal Gasification Project

Prepared for

U.S. Bureau of Land Management

August 1981

Woodward-Clyde Consultants
Three Embarcadero Center, Suite 700, San Francisco, CA 94111

60576C

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Appendix A

ESTIMATED ENERGY REQUIREMENTS, ROCHELLE MINE

Estimates based on an average annual coal production of 11.0 million tons, and an average annual overburden movement of 22.3 million yd^3.

Gasoline (Gallons)	Annual Usage
• Pickups, buses, ambulance	120,000
• Service vehicles	60,000
• Miscellaneous	3,300
	183,000

No. 2 Diesel Fuel (Gallons)	
• Bankshooting (ANFO)	61,300
• Overburden Haulage (120 Ton Trucks)	1,530,000
• Overburden Removal Support	175,000
• Coal Drilling	42,000
• Coal Haulage (120 Ton Trucks)	676,800
• Coal Loading/Haulage Support	192,000
• General Support (Roads)	240,000
• Reclamation	162,000
	3,079,600

Electrical Consumption (kWh)	
• Overburden Removal	22,300,000
• Coal Processing	5,575,000
• Shop/Office Support	5,575,000
	33,450,000

Assumptions:

Gasoline

Big Sky - 1981 April YTD ratio = 60 ton/gallon

• Pickups, etc.	=	65%
• Service vehicle	=	33%
• Miscellaneous	=	2%
		100%

Diesel

- Blasting

$$\frac{22{,}300{,}000\ \text{yd}^3}{(3\ \text{yd}^3/\text{lb powder})} \cdot \frac{1\ \text{ton}}{(2000\ \text{lb powder})} \cdot \frac{16.5\ \text{gal diesel}}{\text{ton powder}} = 61{,}325\ \text{gallons}$$

- Overburden Removal Support

(4 trk/set)(3 set/shf)(3 shf/dy)(4.7 hr/shf)(300 dy/yr)(30 gal/hr) = 1,530,000 gal/yr

- Overburden Removal Support

(3 dozers/shf)(3 shf/dy)(5 hr/shf)(300 dy/yr)(13 gal/hr) = 175,500 gal/yr

- Coal Drilling

(2 drill/shf)(2 shf/dy)(5 hr/shf)(210 dy/yr)(10 gal/hr) = 42,000 gal/yr

- Coal Haulage

(10 trk/shf)(2 shf/dy)(4.7 hr/shf)(240 dy/yr)(30 gal/hr) = 676,800 gal/yr

- Coal Loading/Haulage Support

(4 units/shf)(2 shf/dy)(5 hr/shf)(240 dy/yr)(20 gal/hr) = 192,000 gal/yr

- General Support (Roads)

(6 units/shf)(2 shf/dy)(5 hr/shf)(250 dy/yr)(16 gal/hr) = 240,000 gal/yr

- Reclamation

(6 units/shf)(2 shf/dy)(5 hr/shf)(250 dy/yr)(18 gal/hr) = 162,000 gal/yr

Electrical Consumption (kWh)

- 1 yd^3 = 1.5 kWh

- Distribution:
  - Overburden Removal, 85%
  - Coal Processing, 7.5%
  - Shop/Office Support, 7.5%

Appendix B
STREAMS AFFECTED BY THE PROPOSED WYCOALGAS PROJECT

The following tabulations describe streams that would be affected by the proposed railroad, water supply system, and product pipeline. Table A-1 lists streams with average annual flows greater than 5 cubic feet per second (cfs), and Table A-2 those with flows less than 5 cfs. Column headings are explained below:

- "Affected Stream": identifies stream and its tributary sequence.

- "40", "Section", "Township", "Range": describe the affected area to nearest 40-acre subdivision of a section.

- "Activity Category": identifies the project activity, as follows:

  1 = Combs Reservoir and Dam
  2 = Water Pipeline Crossing
  3 = Road Crossing
  4 = Railroad Crossing
  5 = Product Pipeline Crossing
  6 = North Platte River Reentry Channel

- "Possible Exempt": cites applicable portions of Corps of Engineers regulations which could exempt the activity from the need to obtain an Individual 404 Permit. If a possible exemption does exist, the symbols, A, B, and C are used to designate the appropriate section of the regulations. These symbols are described as follows:

A = 33 CFR Section 323.4-2(a)(1) (Average annual flow of affected stream less than 5 cfs)

B = 33 CFR Section 323.4-3(a)(1) (A pipeline crossing, the construction of which will not require a cofferdam or other flow-restricting device)

C = 33 CFR Section 323.4-3(a)(3) (A minor roadway crossing requiring less than 200 cubic yards of fill below the normal flow elevation)

In addition to the activities listed in the attached tables, other project activities that have not yet been specifically identified may affect waters of the United States. Activities relating to the development of the proposed plant site fall into this category. These plant site activities may include pipeline crossings, roadway and railroad crossings, construction of small dam or other embankments, and minor relocation of stream channels. Streams located on the proposed plant site that could be affected are:

1. Unnamed tributaries of Little Lightning Creek (tributary Lightning Creek, tributary Lance Creek, tributary Cheyenne River)

2. Willow Creek and unnamed tributaries thereof (tributary Walker Creek, tributary Lightning Creek, tributary Lance Creek, tributary Cheyenne River)

Since the average annual flow of these streams is less than 5 cfs, they qualify for exemptions under 33 CFR Section 323.4-2(a)(1). Additional exemptions may also apply depending on the activity.

Table A-1

~~WYCOALGAS GASIFICATION PROJECT~~
~~BANNER PROJECT NO. 1003-B~~

~~TABULATION OF~~ PROJECT ACTIVITIES
AFFECTING WATERS OF THE UNITED STATES
WITH AVERAGE ANNUAL FLOW > 5 CFS

16-JUL-81
PAGE 1

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
16	LA PRELE CREEK, TRIB. NORTH PLATTE R.	SWSW	15	33	72	2	B
19	NORTH PLATTE RIVER	SESW	7	33	71	2	NO
20	NORTH PLATTE RIVER	SESW	7	33	71	6	NO
148	LOST CREEK	SENE	34	32	68	5	B
151	MUDDY CREEK	NENW	32	31	67	5	B
171	NORTH PLATTE RIVER	NESW	5	26	65	5	NO
175	LARAMIE RIVER	SWSE	29	26	65	5	B
191	BEAR CREEK, TRIB., HORSE CREEK, TRIB., N. PLATTE RIVER	SWNW	11	19	66	5	B
193	LITTLE BEAR CREEK, TRIB., BEAR CREEK	SWSE	3	18	66	5	B
202	HORSE CREEK	NWSW	3	17	66	5	B
223	LODGEPOLE CREEK	NENW	3	15	66	5	B
234	CROW CREEK	SWNE	5	13	65	5	B

*** END REPORT ***

Table A-2

[redacted]

[redacted] PROJECT ACTIVITIES
AFFECTING WATERS OF THE UNITED STATES

17-JUL-81
PAGE 1

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
1	LITTLE BOX ELDER CK, TRIB., BOX ELDER CK, TRIB., NORTH PLATTE R.	NWNW	2	32	74	2	AB
2	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	NWNE	2	32	74	2	AB
3	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	NWNE	2	32	74	2	AB
4	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	NWNE	12	32	74	2	AB
5	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	NESE	1	32	74	2	AB
6	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	NWSE	1	32	74	2	AB
7	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	SESW	31	33	74	2	AB
8	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	SWNW	6	32	73	2	AB
9	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	NWNE	6	32	73	2	AB
10	UNNAMED TRIBUTARY, LITTLE BOX ELDER CK.	SESW	32	33	73	2	AB
11	UNNAMED TRIBUTARY, NORTH PLATTE RIVER	NENW	28	33	73	2	AB
12	ALKALI GULCH, TRIB. NORTH PLATTE RIVER	SWSE	8	32	73	2	AB
13	ALKALI GULCH, TRIB. NORTH PLATTE RIVER	SWSE	8	32	73	2	AB
14	ALKALI GULCH, TRIB. NORTH PLATTE RIVER	NENW	26	33	73	2	AB
15	UNNAMED TRIBUTARY, ALKALI GULCH	NWNE	27	33	73	2	AB
16	LA PRELE CREEK, TRIB. NORTH PLATTE R.	SWSW	15	33	72	2	B
17	UNNAMED TRIBUTARY, LA PRELE CREEK	SENW	21	33	72	2	AB
18	UNNAMED TRIBUTARY, LA PRELE CREEK	NENE	30	33	72	2	AB
19	NORTH PLATTE RIVER	SESW	7	33	71	2	NO

WYCOALGAS GASIFICATION PROJECT
BANNER PROJECT NO. 1803-5

TABULATION OF PROJECT ACTIVITIES
AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
20	NORTH PLATTE RIVER	SESW	7	33	71	6	NO
21	SOLDIER CK, TRIB. NORTH PLATTE R.	NWNW	7	33	71	1	A
22	SOLDIER CREEK	SESE	12	33	70	3	AC
23	UNNAMED TRIBUTARY, NORTH PLATTE RIVER	NENW	2	33	72	3	AC
24	UNNAMED TRIBUTARY, SOLDIER CREEK	NENW	8	33	71	2	AB
25	UNNAMED TRIBUTARY, SOLDIER CREEK	SESE	5	33	71	2	AB
26	UNNAMED TRIBUTARY, SOLDIER CREEK	NWSW	4	33	71	2	AB
27	UNNAMED TRIBUTARY, SOLDIER CREEK	NENW	4	33	71	2	AB
28	UNNAMED TRIBUTARY, SOLDIER CREEK	NESE	33	34	71	2	AB
29	UNNAMED TRIBUTARY, SOLDIER CREEK	SWNW	34	34	71	2	AB
30	UNNAMED TRIBUTARY, SOLDIER CREEK	NWNE	26	34	71	2	AB
31	UNNAMED TRIBUTARY, SOLDIER CREEK	NWNE	26	34	71	2	AB
32	UNNAMED TRIBUTARY, SOLDIER CREEK	SESW	23	34	71	2	AB
33	UNNAMED TRIBUTARY, SOLDIER CREEK	SWNW	23	34	71	2	AB
34	UNNAMED TRIBUTARY, SOLDIER CREEK	NENE	28	34	71	3	AC
35	UNNAMED TRIBUTARY, SOLDIER CREEK	NESW	15	34	71	2	AB
36	UNNAMED TRIBUTARY, SOLDIER CREEK	SENW	15	34	71	2	AB
37	HARVEY GULCH, TRIB., NORTH PLATTE RIVER	NESW	25	34	71	2	AB
38	UNNAMED TRIB, WALKER CK, TRIB, LIGHTNING CK, TRIB, LANCE CK, TRIB, CHEYENNE RIVER	NESW	18	34	70	2	AB
39	UNNAMED TRIB, WALKER CK, TRIB, LIGHTNING CK, TRIB, LANCE CK, TRIB, CHEYENNE RIVER	NWSE	8	34	70	2	AB

WYCOALGAS GASIFICATION PROJECT
BANNER PROJECT NO. 1803-5

TABULATION OF PROJECT ACTIVITIES AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
40	UNNAMED TRIB, WALKER CK, TRIB, LIGHTNING CK, TRIB, LANCE CK, TRIB, CHEYENNE RIVER	SENE	8	34	70	2	AB
41	UNNAMED TRIB, WALKER CK, TRIB, LIGHTNING CK, TRIB, LANCE CK, TRIB, CHEYENNE RIVER	SWSE	4	34	70	2	AB
42	LIGHTNING CREEK	SWNE	4	35	70	4	AC
43	UNNAMED TRIBUTARY, LIGHTNING CREEK	SWSE	23	35	71	2	AB
44	UNNAMED TRIBUTARY, LIGHTNING CREEK	SWNE	23	35	71	2	AB
45	UNNAMED TRIBUTARY, LIGHTNING CREEK	NENE	23	35	71	2	AB
46	UNNAMED TRIBUTARY, LIGHTNING CREEK	NESE	14	35	71	3	AC
47	UNNAMED TRIBUTARY, LIGHTNING CREEK.	NESE	14	35	71	2	AB
48	ALEXANDER DRAW, TRIB., LIGHTNING CREEK	NENE	24	35	71	2	AB
49	UNNAMED TRIBUTARY, LITTLE LIGHTNING CK, TRIB., LIGHTNING CREEK	NESW	3	34	71	2	AB
50	UNNAMED TRIBUTARY, LITTLE LIGHTNING CK, TRIB., LIGHINING CREEK	SENW	3	34	71	3	AC
51	UNNAMED TRIBUTARY, LITTLE LIGHTNING CK, TRIB., LIGHTNING CREEK	NESE	34	35	71	2	AB
52	UNNAMED TRIBUTARY, LITTLE LIGHTNING CK, TRIB., LIGHTNING CREEK	NENW	35	35	71	2	AB

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
53	UNNAMED TRIBUTARY, LITTLE LIGHTNING CK, TRIB., LIGHTNING CREEK	NESW	13	34	71	2	AB
54	UNNAMED TRIBUTARY, LITTLE LIGHTNING CK, TRIB., LIGHTNING CREEK	SWSE	11	34	71	2	AB
55	UNNAMED TRIBUTARY, LITTLE LIGHTNING CK, TRIB., LIGHTNING CREEK	NESE	26	35	71	2	AB
56	LITTLE LIGHTNING CREEK	NWSE	25	35	71	2	AB
57	LITTLE LIGHTNING CREEK	SWNW	30	35	70	2	AB
58	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	NESE	30	35	70	2	AB
59	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	SWSE	29	35	70	2	AB
60	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	SESE	29	35	70	2	AB
61	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	NENW	3	34	70	2	AB
62	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	SESW	34	35	70	3	AC
63	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	SWSE	34	35	70	2	AB
64	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	NESW	24	35	70	3	AC
65	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	NWNE	33	35	70	2	AB

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
66	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	SWNE	28	35	70	4	AC
67	UNNAMED TRIBUTARY, TRIB., LITTLE LIGHTNING CREEK	SESE	16	35	70	4	AC
68	UNNAMED TRIBUTARY, LIGHTNING CREEK	SWSE	33	36	70	4	AC
69	UNNAMED TRIB,BOX CK,TRIB,LIGHTNING CK,TRIB,LANCE CK,TRIB,CHEYENNE RIVER	NWSE	21	36	70	4	AC
70	BOX CREEK	SESE	9	36	70	4	AC
71	UNNAMED TRIBUTARY, BOX CREEK	SENE	9	36	70	4	AC
2	MIKES DRAW, TRIB. BOX CREEK	SWSW	34	37	70	4	AC
73	IRETON DRAW, TRIB. REEVES DRAW, TRIB. DRY CK, TRIB. LIGHTNING CK.	SWSW	15	37	70	4	AC
74	UNNAMED TRIBUTARY, REEVES DRAW	NWSW	10	37	70	4	AC
75	REEVES DRAW	SWNW	10	37	70	4	AC
76	DRY CREEK	NWNW	3	37	70	4	AC
77	SHELDON DRAW, TRIB., DRY CREEK	NWNW	34	38	70	4	AC
78	UNNAMED TRIB,WILLOW DRAW,TRIB,DRY FORK CHEYENNE R, TRIB, CHEYENNE RIVER	NWSE	3	38	70	4	AC
79	UNNAMED TRIB,WILLOW DRAW,TRIB,DRY FORK CHEYENNE R, TRIB, CHEYENNE RIVER	SWNE	3	38	70	4	AC
80	UNNAMED TRIB,WILLOW DRAW,TRIB,DRY FORK CHEYENNE R, TRIB, CHEYENNE RIVER	NWSE	34	39	70	4	AC

TABULATION OF PROJECT ACTIVITIES
AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
81	UNNAMED TRIB, WILLOW DRAW, TRIB, DRY FORK CHEYENNE R, TRIB, CHEYENNE RIVER	SENE	34	39	70	4	AC
82	CONLEY DRAW, TRIB., WILLOW DRAW	SWNW	35	39	70	4	AC
83	UNNAMED TRIBUTARY, WILLOW DRAW	NWNW	35	39	70	4	AC
84	UNNAMED TRIBUTARY, WILLOW DRAW	NWSW	26	39	70	4	AC
85	WILLOW DRAW	NESE	22	39	70	4	AC
86	DRY FORK CHEYENNE RIVER	SWSW	14	39	70	4	AC
87	FORD DRAW, TRIB., DRY FORK CHEY RIV.	NWNE	14	39	70	4	AC
88	UNNAMED TRIBUTARY, DRY FORK CHEY RIVER	SESE	11	39	70	4	AC
89	UNNAMED TRIBUTARY, DRY FORK CHEY RIVER	NWSW	12	39	70	4	AC
90	BAD CREEK, TRIB., DRY FORK CHEY. RIVER	NENW	12	39	70	4	AC
91	WOODY CREEK, TRIB., DRY FORK CHEY. RIVER	SWSE	1	39	70	4	AC
92	UNNAMED TRIBUTARY, WOODY CREEK	SWSE	1	39	70	4	AC
93	UNNAMED TRIBUTARY, WOODY CREEK	SENE	1	39	70	4	AC
94	UNNAMED TRIBUTARY, WOODY CREEK	SWSW	31	40	69	4	AC
95	UNNAMED TRIBUTARY, DRY FORK CHEY. RIVER	SENW	31	40	69	4	AC
96	UNNAMED TRIBUTARY, DRY FORK CHEY. RIVER	NWNE	31	40	69	4	AC
97	UNNAMED TRIBUTARY, DRY FORK CHEY. RIVER	SENE	30	40	69	4	AC
98	COAL BANK DRAW, TRIB., ANTELOPE CK, TRIB., DRY FORK CHEY. RIVER	SENE	19	40	69	4	AC
99	UNNAMED TRIBUTARY, COAL BANK DRAW	SESE	18	40	69	4	AC

WYCOALGAS GASIFICATION PROJECT
BANNER PROJECT NO. 1803-5

TABULATION OF PROJECT ACTIVITIES AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
100	UNNAMED TRIBUTARY, ANTELOPE CREEK	NESE	18	40	69	4	AC
101	UNNAMED TRIBUTARY, ANTELOPE CREEK	SENE	18	40	69	4	AC
102	UNNAMED TRIBUTARY, ANTELOPE CREEK	NESW	7	40	69	4	AC
103	UNNAMED TRIBUTARY, ANTELOPE CREEK	SWNW	7	40	69	4	AC
104	UNNAMED TRIBUTARY, ANTELOPE CREEK	NWNW	7	40	69	4	AC
105	UNNAMED TRIBUTARY, ANTELOPE CREEK	SESE	1	40	70	4	AC
106	UNNAMED TRIBUTARY, ANTELOPE CREEK	SESE	1	40	70	4	AC
107	UNNAMED TRIBUTARY, ANTELOPE CREEK	SENE	1	40	70	4	AC
108	UNNAMED TRIBUTARY, ANTELOPE CREEK	SESW	36	41	70	4	AC
109	UNNAMED TRIBUTARY, ANTELOPE CREEK	NWSW	36	41	70	4	AC
110	ANTELOPE CREEK	SWNE	35	41	70	4	AC
111	PORCUPINE CK., TRIB. ANTELOPE CK.	SENW	35	41	70	4	AC
112	PORCUPINE CK., TRIB. ANTELOPE CK.	SENW	35	41	70	4	AC
113	PORCUPINE CK., TRIB. ANTELOPE CK.	NWNW	35	41	70	4	AC
114	PORCUPINE CK., TRIB. ANTELOPE CK.	NESE	21	41	70	4	AC
115	PORCUPINE CK., TRIB. ANTELOPE CK.	SWNE	21	41	70	4	AC
116	PORCUPINE CK., TRIB. ANTELOPE CK.	SWSE	16	41	70	4	AC
117	PORCUPINE CK., TRIB. ANTELOPE CK.	SWNE	16	41	70	4	AC
118	PORCUPINE CK., TRIB. ANTELOPE CK.	SENE	16	41	70	4	AC
119	UNNAMED TRIBUTARY, WALKER CREEK	SWNE	11	34	70	5	AB
120	WALKER CREEK	NWSE	11	34	70	5	AB

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
121	UNNAMED TRIBUTARY, WALKER CREEK	NENW	24	34	70	5	AB
122	UNNAMED TRIBUTARY, WALKER CREEK	SWNE	24	34	70	5	AB
123	UNNAMED TRIBUTARY, WALKER CREEK	NWSE	30	34	69	5	AB
124	UNNAMED TRIBUTARY, WALKER CREEK	SESE	30	34	69	5	AB
125	UNNAMED TRIBUTARY, WALKER CREEK	NWSW	32	34	69	5	AB
126	UNNAMED TRIB, SIMPSON DR, TRIB, WEST FORK SHAWNEE CK, TRIB, SHAWNEE CK, TRIB, N. PLATTE RIVER	NENE	9	33	69	5	AB
127	UNNAMED TRIB, SIMPSON DR, TRIB, WEST FORK SHAWNEE CK, TRIB, SHAWNEE CK, TRIB, N. PLATTE RIVER	NESE	10	33	69	5	AB
128	UNNAMED TRIB, MIDDLE FORK SHAWNEE CK, TRIB, SHAWNEE CK.	SESW	11	33	69	5	AB
129	UNNAMED TRIB, MIDDLE FORK SHAWNEE CK, TRIB, SHAWNEE CK.	NWNE	14	33	69	5	AB
130	UNNAMED TRIB, MIDDLE FORK SHAWNEE CK, TRIB, SHAWNEE CK.	NENW	13	33	69	5	AB
131	UNNAMED TRIB, MIDDLE FORK SHAWNEE CK, TRIB, SHAWNEE CK.	SENE	13	33	69	5	AB
132	UNNAMED TRIB, MIDDLE FORK SHAWNEE CK, TRIB, SHAWNEE CK.	NESW	18	33	68	5	AB
133	UNNAMED TRIB, EAST FORK SHAWNEE CREEK, TRIB., SHAWNEE CREEK	NENW	29	33	68	5	AB

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TABULATION OF PROJECT ACTIVITIES
AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
134	UNNAMED TRIB, EAST FORK SHAWNEE CREEK, TRIB., SHAWNEE CREEK	SENW	29	33	68	5	AB
135	EAST FORK SHAWNEE CREEK	SESE	29	33	68	5	AB
136	WHACKOFF CREEK, TRIB, EAST FORK SHAWNEE CREEK	SWNW	33	33	68	5	AB
137	UNNAMED TRIBUTARY, WHACKOFF CREEK	NESW	33	33	68	5	AB
138	UNNAMED TRIBUTARY, EAST FORK SHAWNEE CREEK	SENW	4	32	68	5	AB
139	UNNAMED TRIBUTARY, EAST FORK SHAWNEE CREEK	SESW	4	32	68	5	AB
40	UNNAMED TRIBUTARY, EAST FORK SHAWNEE CREEK	NWNE	9	32	68	5	AB
141	UNNAMED TRIBUTARY, LOST CREEK, TRIB., NORTH PLATTE RIVER	NWSE	9	32	68	5	AB
142	UNNAMED TRIBUTARY, LOST CREEK, TRIB., NORTH PLATTE RIVER	SWSE	9	32	68	5	AB
143	UNNAMED TRIBUTARY, LOST CREEK, TRIB., NORTH PLATTE RIVER	SWNE	16	32	68	5	AB
144	UNNAMED TRIBUTARY, LOST CREEK, TRIB., NORTH PLATTE RIVER	NENE	21	32	68	5	AB
145	UNNAMED TRIBUTARY, LOST CREEK, TRIB., NORTH PLATTE RIVER	NWSW	22	32	68	5	AB
146	UNNAMED TRIBUTARY, LOST CREEK, TRIB., NORTH PLATTE RIVER	SENW	27	32	68	5	AB
147	UNNAMED TRIBUTARY, LOST CREEK, TRIB., NORTH PLATTE RIVER	NWSE	27	32	68	5	AB

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
148	LOST CREEK	SENE	34	32	68	5	B
149	UNNAMED TRIBUTARY, LOST CREEK	NESW	2	31	68	5	AB
150	UNNAMED TRIBUTARY, MUDDY CREEK, TRIB., NORTH PLATTE RIVER	SWNE	30	31	67	5	AB
151	MUDDY CREEK	NENW	32	31	67	5	B
152	SPANISH CREEK, TRIB., MUDDY CREEK	NENE	5	30	67	5	AB
153	UNNAMED TRIB., WILLOW CREEK, TRIB., MUDDY CREEK	NWNW	24	30	67	5	AB
154	UNNAMED TRIB., WILLOW CREEK, TRIB., MUDDY CREEK	NWNW	24	30	67	5	AB
155	WILLOW CREEK	NWNE	24	30	67	5	AB
56	UNNAMED TRIBUTARY, WILLOW CREEK	SWSW	20	30	66	5	AB
157	UNNAMED TRIBUTARY, BROOM CREEK, TRIB., NORTH PLATTE RIVER	SWNE	3	29	66	5	AB
158	UNNAMED TRIBUTARY, BROOM CREEK, TRIB., NORTH PLATTE RIVER	SWSE	3	29	66	5	AB
159	UNNAMED TRIBUTARY, BROOM CREEK, TRIB., NORTH PLATTE RIVER	NWSW	14	29	66	5	AB
160	BROOM CREEK	SWNE	23	29	66	5	AB
161	UNNAMED TRIBUTARY, PATTEN CREEK, TRIB., BROOM CREEK	SWNW	25	29	66	5	AB
162	UNNAMED TRIBUTARY, PATTEN CREEK, TRIB., BROOM CREEK	SWSE	25	29	66	5	AB
163	PATTEN CREEK	NENE	36	29	66	5	AB
164	UNNAMED TRIBUTARY, PATTEN CREEK	SWNW	6	28	65	5	AB
165	SAM DRAW, TRIB., PATTEN CREEK	SESE	7	28	65	5	AB
166	UNNAMED TRIBUTARY, WHALEN CANYON, TRIB., N. PLATTE RIVER	SENW	20	28	65	5	AB

TABULATION OF PROJECT ACTIVITIES
AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
167	UNNAMED TRIBUTARY, WHALEN CANYON, TRIB., N. PLATTE RIVER	NENW	29	28	65	5	AB
168	UNNAMED TRIBUTARY, WHALEN CANYON, TRIB., N. PLAITE RIVER	NESW	17	27	65	5	AB
169	WHALEN CANYON	SENW	29	27	65	5	AB
170	WHALEN CANYON	SENW	32	27	65	5	AB
171	NORTH PLATTE RIVER	NESW	5	26	65	5	NO
172	UNNAMED TRIBUTARY, LARAMIE RIVER, TRIB., NORTH PLATTE RIVER	SENW	20	26	65	5	AB
173	UNNAMED TRIBUTARY, LARAMIE RIVER, TRIB., NORTH PLATTE RIVER	NENW	29	26	65	5	AB
174	UNNAMED TRIBUTARY, LARAMIE RIVER, TRIB., NORTH PLATTE RIVER	NESW	29	26	65	5	AB
175	LARAMIE RIVER	SWSE	29	26	65	5	B
176	UNNAMED TRIBUTARY, LARAMIE RIVER	SENE	32	26	65	5	AB
177	UNNAMED TRIBUTARY, LARAMIE RIVER	NESE	32	26	65	5	AB
178	UNNAMED TRIBUTARY, LARAMIE RIVER	NESE	8	25	65	5	AB
179	UNNAMED TRIBUTARY, LARAMIE RIVER	NENE	17	25	65	5	AB
180	UNNAMED TRIBUTARY, LARAMIE RIVER	NWSE	17	25	65	5	AB
181	UNNAMED TRIBUTARY, DEER CREEK, TRIB. NORTH PLATTE RIVER	SENW	32	25	65	5	AB
182	DEER CREEK	SESW	5	24	65	5	AB
183	UNNAMED TRIBUTARY, DEER CREEK	SESW	8	24	65	5	AB

TABULATION OF PROJECT ACTIVITIES
AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
184	CHERRY CREEK, TRIB., CLOSED BASIN	SESW	7	24	65	5	AB
185	UNNAMED TRIBUTARY, CLOSED BASIN	SWSE	7	23	65	5	AB
186	UNNAMED TRIBUTARY, CLOSED BASIN	NENW	18	23	65	5	AB
187	UNNAMED TRIBUTARY, CLOSED BASIN	NWNW	19	23	65	5	AB
188	UNNAMED TRIBUTARY, CLOSED BASIN	SWNW	19	23	65	5	AB
189	UNNAMED TRIBUTARY, CLOSED BASIN	SESE	24	23	66	5	AB
190	UNNAMED TRIBUTARY, BOX ELDER CREEK, TRIB., CLOSED BASIN	NENE	23	21	66	5	AB
191	BEAR CREEK, TRIB., HORSE CREEK, TRIB., N. PLATTE RIVER	SWNW	11	19	66	5	B
192	UNNAMED TRIBUTARY, BEAR CREEK	SWSW	14	19	66	5	AB
193	LITTLE BEAR CREEK, TRIB., BEAR CREEK	SWSE	3	18	66	5	B
194	UNNAMED TRIBUTARY, CLOSED BASIN	SENW	10	18	66	5	AB
195	UNNAMED TRIBUTARY, LITTLE BEAR CREEK	NWSW	15	18	66	5	AB
196	UNNAMED TRIBUTARY, LITTLE BEAR CREEK	SWSW	15	18	66	5	AB
197	UNNAMED TRIBUTARY, LITTE BEAR CREEK	NWNW	22	18	66	5	AB
198	UNNAMED TRIBUTARY, HORSE CREEK	NWNW	27	18	66	5	AB
199	UNNAMED TRIBUTARY, HORSE CREEK	SWSW	27	18	66	5	AB
200	UNNAMED TRIBUTARY, HORSE CREEK	NWSW	34	18	66	5	AB
201	UNNAMED TRIBUTARY, HORSE CREEK	NWNW	3	17	66	5	AB
202	HORSE CREEK	NWSW	3	17	66	5	B
203	UNNAMED TRIBUTARY, HORSE CREEK	NENE	16	17	66	5	AB

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
204	UNNAMED TRIBUTARY, HORSE CREEK	NESE	16	17	66	5	AB
205	UNNAMED TRIBUTARY, HORSE CREEK	NENE	21	17	66	5	AB
206	TRAIL CREEK, TRIB., HORSE CREEK	SESE	28	17	66	5	AB
207	CHIVINGTON DRAW, TRIB., SPRING CK., TRIB., LODGEPOLE CK.	NWNW	34	17	66	5	AB
208	UNNAMED TRIBUTARY, CHIVINGTON DRAW	NWSW	34	17	66	5	AB
209	UNNAMED TRIBUTARY, CHIVINGTON DRAW	NWNW	3	16	66	5	AB
210	UNNAMED TRIBUTARY, CHIVINGTON DRAW	SWNW	3	16	66	5	AB
211	UNNAMED TRIB., ANTELOPE DRAW, TRIB., CHIVINGTON DRAW	NWNW	10	16	66	5	AB
212	ANTELOPE DRAW	NWNW	10	16	66	5	AB
213	UNNAMED TRIBUTARY, ANTELOPE DRAW	SWSW	10	16	66	5	AB
214	UNNAMED TRIBUTARY, ANTELOPE DRAW	NWNW	15	16	66	5	AB
215	UNNAMED TRIBUTARY, ANTELOPE DRAW	SWSW	15	16	66	5	AB
216	UNNAMED TRIBUTARY, ANTELOPE DRAW	SWNW	22	16	66	5	AB
217	UNNAMED TRIBUTARY, ANTELOPE DRAW	SWNW	22	16	66	5	AB
218	UNNAMED TRIBUTARY, ANTELOPE DRAW	SWSW	22	16	66	5	AB
219	UNNAMED TRIBUTARY, LODGEPOLE CREEK	SWNW	27	16	66	5	AB
220	UNNAMED TRIBUTARY, LODGEPOLE CREEK	SWSW	27	16	66	5	AB
221	UNNAMED TRIBUTARY, LODGEPOLE CREEK	SWSW	27	16	66	5	AB
222	UNNAMED TRIBUTARY, LODGEPOLE CREEK	NWNW	34	16	66	5	AB

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
223	LODGEPOLE CREEK	NENW	3	15	66	5	B
224	UNNAMED TRIBUTARY, LODGEPOLE CREEK	SESE	3	15	66	5	AB
225	UNNAMED TRIBUTARY, NINEMILE DRAW, TRIB., LODGEPOLE CREEK	SWNW	11	15	66	5	AB
226	UNNAMED TRIBUTARY, NINEMILE DRAW, TRIB., LODGEPOLE CREEK	NWSW	11	15	66	5	AB
227	NINEMILE DRAW	SWNE	14	15	66	5	AB
228	UNNAMED TRIBUTARY, NINEMILE DRAW	SENE	23	15	66	5	AB
229	UNNAMED TRIBUTARY, LODGEPOLE CREEK	SESE	25	15	66	5	AB
30	UNNAMED TRIBUTARY, MUDDY CREEK, TRIB., LODGEPOLE CREEK	SENE	1	14	66	5	AB
231	UNNAMED TRIBUTARY, MUDDY CREEK, TRIB., LODGEPOLE CREEK	NWNW	7	14	65	5	AB
232	UNNAMED TRIBUTARY, CROW CREEK, TRIB., SOUTH PLATTE RIVER	SENE	32	14	65	5	AB
233	UNNAMED TRIBUTARY, CROW CREEK, TRIB., SOUTH PLATTE RIVER	SESE	32	14	65	5	AB
234	CROW CREEK	SWNE	5	13	65	5	B
235	UNNAMED TRIBUTARY, CROW CREEK	NWNW	8	13	65	5	AB
236	UNNAMED TRIBUTARY, CLOSED BASIN	NESE	24	13	66	5	AB
237	PORTER DRAW, TRIB., PORTER CREEK, TRIB., CROW CREEK	NWNW	36	13	66	5	AB
238	LITTLE SIMPSON CREEK, TRIB., SIMPSON CK.	NESW	2	12	66	5	AB
239	UNNAMED TRIB, SIMPSON CK, TRIB, PORTER CK, TRIB, CROW CK, TRIB, S. PLATTE RIVER	SESE	10	12	66	5	AB

TABULATION OF PROJECT ACTIVITIES AFFECTING WATERS OF THE UNITED STATES

MAP NR	AFFECTED STREAM	'40'	SECTION	TOWN-SHIP	RANGE	ACTIVITY CATEGORY	POSSIBLE EXEMPT.
240	UNNAMED TRIB, SIMPSON CK, TRIB, PORTER CK, TRIB, CROW CK, TRIB, S.PLATTE RIVER	NWNE	15	12	66	5	AB
241	UNNAMED TRIB, SIMPSON CK, TRIB, PORTER CK, TRIB, CROW CK, TRIB, S.PLATTE RIVER	SESW	15	12	66	5	AB
242	UNNAMED TRIB., OWL CREEK, TRIB., SOUTH PLATTE RIVER	SWSE	21	12	66	5	AB
243	UNNAMED TRIB., OWL CREEK, TRIB., SOUTH PLATTE RIVER	SESE	29	12	66	5	AB
244	UNNAMED TRIB., OWL CREEK, TRIB., SOUTH PLATTE RIVER	NENE	32	12	66	5	AB
245	UNNAMED TRIB., OWL CREEK, TRIB., SOUTH PLATTE RIVER	NWSE	32	12	66	5	AB

*** END REPORT ***

APPENDIX C-1. PLANT SITE STUDIES, BIOLOGICAL DATA

BIOLOGICAL INVENTORY

PREPARED BY

ECOLOGY CONSULTANTS, INCORPORATED
Fort Collins, Colorado

and

SERNCO INCORPORATED
Denver, Colorado

List of Figures

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A. INTRODUCTION

The following biological inventory was compiled by biologists at Ecology Consultants Incorporated (ECI) in Fort Collins, Colorado and SERNCO in Denver, Colorado for the Wyoming Coal Gas Company (WCGS) and the Rochelle Mine Company.

WCGS plans to construct a coal gasification plant in conjunction with the Rochelle surface coal mine. At the inception of the project, two plant sites were proposed by WCGS. ECI was retained by SERNCO in May 1973 to prepare a biological inventory for these two plant sites along with the mine site. This analysis was submitted to SERNCO in March 1974 and is presented in subsection B of this appendix. The plant sites are referred to with approximate reference to the mine, as the east plant site (T40N, R69W Sections 33,34,28 and 21) and the south plant site (T35N, R70W Sections 26,27,34 and 35).

Four months later the east plant site was rejected by WCGS and a new site (north plant site) was proposed for the following reasons: (1) the north site (T41N, R71W, Sections 4, 5; T42N, R71W, Sections 32, 33) is 15 miles nearer the Wyoming highway 59 than the east site thus eliminating 15 miles of supply and transport corridors; (2) the north site is on the proposed Burlington Northern, Chicago and North Western Rail line thus eliminating a 15 mile rail spur; (3) the north plant site does not contain significant hydrological features such as were observed on the east plant site (Beckwith Creek).

The biological inventory of the north site was prepared by SERNCO and is presented in subsection C of this appendix. Clearly the time available for the preparation of the north plant site inventory was very limited and the resulting inventory is not as detailed and in-depth a study as the previous site studies. However, the mine site is biologically similar to the north plant site and only 3 miles east of it. Therefore, any biological assessments of the mine site aquatic and terrestrial communities should also be representative of the north plant site, and it is felt that the lack of north plant site data is not detrimental to any environmental considerations.

B. MINE SITE, SOUTH PLANT SITE AND EAST PLANT SITE BIOLOGICAL INVENTORY

At the request of SERNCO, Inc. and on behalf of Wyoming Coal Gas Company and Rochelle Coal Company (WCGC/RCC) Ecology Consultants, (ECI) has undertaken an information search and field survey to provide ecological information pertinent to a coal-gasification project and surface coal mine in northeast Wyoming. Information thus obtained was detailed in a series of reports. In this appendix to the Environmental Assessment, the study areas are characterized, methods of data collection and analysis are described and a summary of major results are presented. ECI interpretations of these results were provided in separate biological baseline, ecological interrelationships, biological impacts and recommended monitoring and mitigation reports. These have been incorporated into the main body of the Environmental Assessment.

1. Local Physical and Biotic Environments

Initial field studies were conducted on the proposed Rochelle mine area and at the east and south plant sites from June through December, 1973. All three study areas lie within the Chevenne River drainage basin (figure A-1) in Campbell and Converse Counties, Wyoming. The "rain shadow" effect of the nearby Rocky Mountain front range creates a semi-arid climate in the region, producing an average annual precipitation of only 12.4 inches (about one-fourth of which falls during winter months as snow). Greatest precipitation typically occurs during early summer, although wide variations in seasonal distribution and total precipitation are common. Growing seasons, or frost-free summer periods, for the area surveyed are approximately 104 days. Annual ranges of temperature vary from 103 degrees F during the summer to as low as −38 degrees F during winter periods. Located in a westerly wind zone, the area receives almost continuous, and often, strong winds throughout much of the year.

Topography of the general area varies from gently rolling or undulating land features to rough breaks and erosion patterns which extend to small ephemeral streams. Mountain or foothill ranges are not found in the vicinity and the elevation varies only a few hundred feet throughout the area encompassing the sampling locations.

According to Soil Conservation Service soil classifications, approximately one-half of the mine lease area is listed as eroded "rough breaks", and the remaining rolling uplands are composed of soils, primarily Ulm loam and Renohill clay loam, that are typical of the region. Small alluvial deposits of saline, alkaline, or saline-alkaline soils are found within the region but represent no more than one percent of the total area and are restricted to narrow bands along primarily drainages.

Water flow, even in primary drainages, is ephemeral with flow rates that are highly dependent upon local soils, vegetative cover and precipitation. Standing water is limited to gully-plug reservoirs and deeper holes along stream courses, most of which dry up completely during drought periods. The components of local aquatic ecosystems are variously adapted to this unpredictable character of their environment.

Associated with a northeast trending gradient of increasing precipitation is a corresponding gradient in vegetation such that study areas are located in a zone of transition between Northern Desert Shrub vegetation, typical of the more westward Great Basin Province, and Shortgrass Plains vegetation, which predominates farther east. Thus the vegetation of the study areas is largely a mixture of sagebrush and short grasses, the mix varying considerably according to local conditions. Associated with this transi-

tional vegetation is a group of animals that is unexpectedly diverse considering the aridity of the region. This diversity results partly from an "edge effect" by which animal species characteristically found only in Northern Desert Shrub vegetation or in the Shortgrass Plains are found mixed together in the same area.

That field studies are important in such a region is demonstrated by species' range maps which show distributional limits of many animal species or subspecies occurring within the area to be investigated. In such cases only on-site observations can verify the presence or absence of a particular taxon. Therefore, at each study area, a reconnaissance was made to determine the existing aquatic habitats and major vegetation types. Locations representative of the predominant habitat type in each proposed area of activity were selected for quantitative study and locations representative of the broad range of different habitats throughout each area were selected for additional inventory. In terrestrial studies, certain of the sampling locations chosen for vegetation sampling were also systematically sampled for small mammals, birds, and invertebrates. The following is a summary of exact sampling locations, methods of sampling, and the resulting biological information.

2. Biological Inventories

a. Aquatic Studies

1) General Hydrologic Environment

The Cheyenne River Basin is bounded generally by the parallels 42°50′ north latitude and 101°3′ and 106° west longitude (figure A-1). The stream, originating as a number of small tributaries in Campbell and Converse Counties, Wyoming, drains parts of three states in its meandering eastward progression toward a confluence with the Missouri River near Eagle Butte, South Dakota (figures A-1 and A-2). The drainage area included within Wyoming is approximately 7,190 square miles.[1,2]

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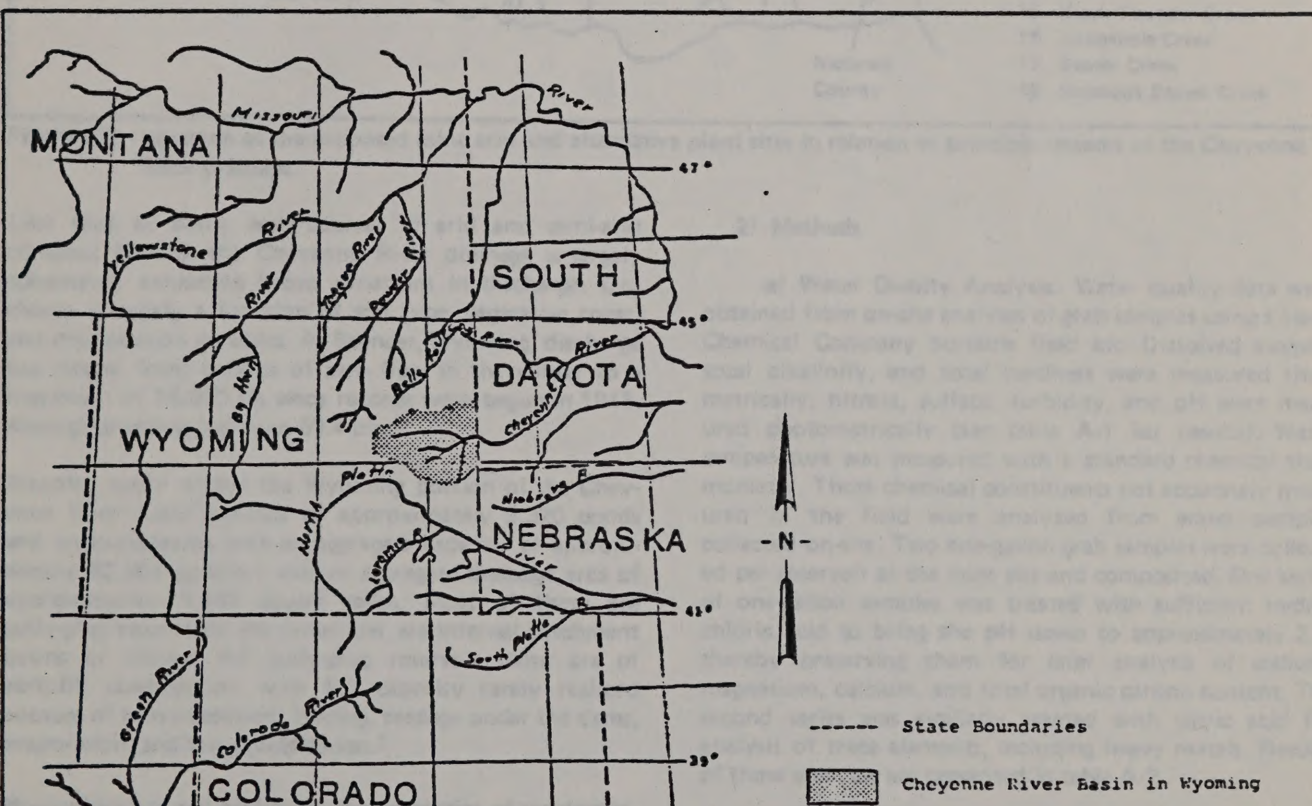
1 Culler, R. C. 1961. Hydrology of stock-water reservoirs in Upper Cheyenne River Basin. *In:* Hydrology of the Upper Cheyenne River Basin. U. S. Geol. Sur. Water-Supply Paper No. 53.

2 Hadley, R. F. and S. A. Schumm. 1961. Sediment sources and drainage-basin characteristics in Upper Cheyenne River Basin. *In:* Hydrology of the Upper Cheyenne River Basin. U. S. Geol. Sur. Water-Supply Paper No. 53.



Source: Veal, D.V. 1959. Water resources of the Cheyenne River Basin, Wyoming, Unpublished M.S. Thesis, Univ. of Wyoming, Laramie.

Figure A-1. Cheyenne River Basin, Wyoming, in relation to regional drainage patterns.

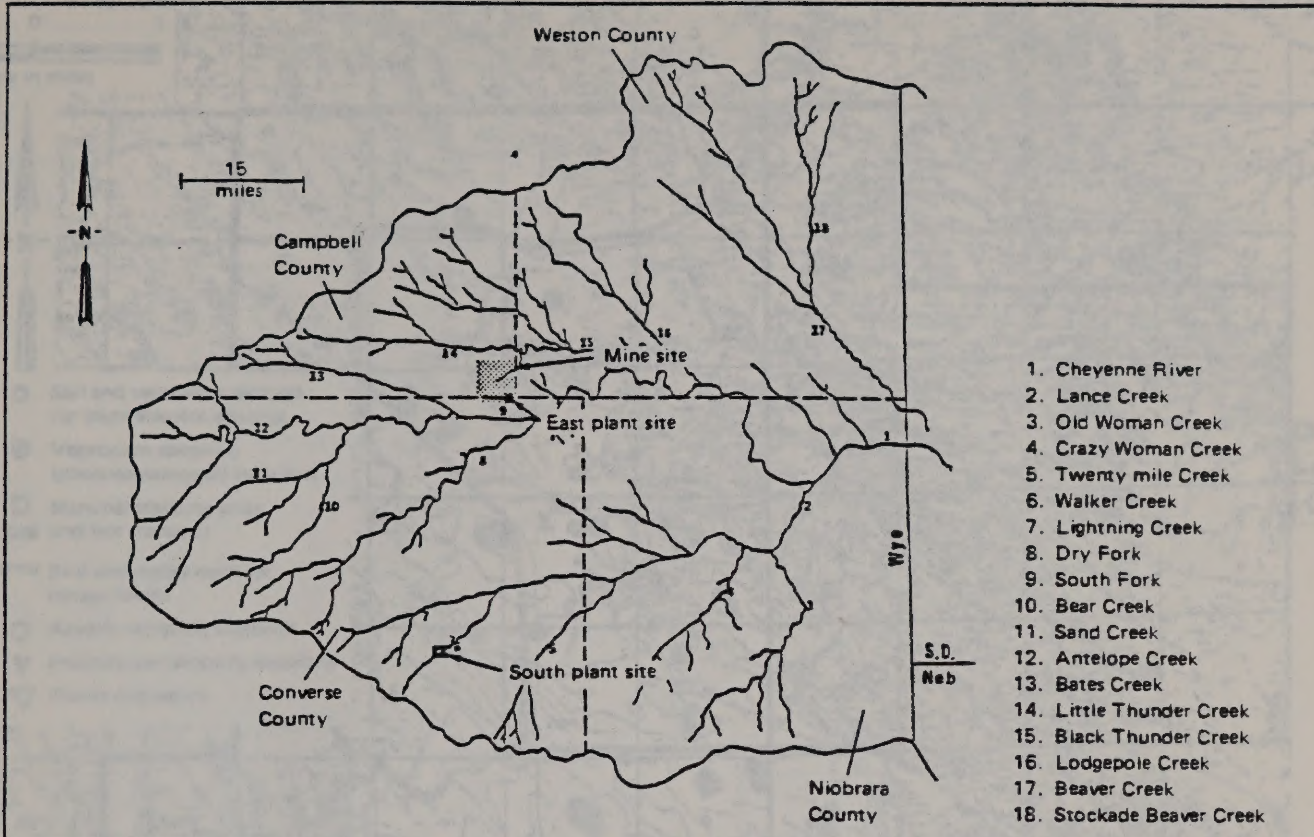


Figure A-2. Location of the proposed mine area and alternative plant sites in relation to principle streams of the Cheyenne River drainage.

Like that of many watercourses in arid and semi-arid climates, flow in the Cheyenne River drainage is largely ephemeral, exhibiting broad variations in discharge. Discharge is largely a function of soil type, vegetative cover, and precipitation variables. At Spencer, Wyoming, discharge has ranged from periods of zero flow in the winter to a maximum of 16,000 cfs since records were begun in 1948. Average discharge has been 59.4 cfs.

Standing water within the Wyoming portion of the Cheyenne River basin consists of approximately 9,320 ponds and impoundments with an aggregate capacity of approximately 52,360 acre-feet and an aggregate drainage area of approximately 4,440 square miles. Most of these are gully-plug reservoirs; the remainder are internal catchment basins or playas. All gully-plug reservoir dams are of earthfill construction with full capacity rarely realized because of heavy sediment loading, seepage under the dams, evaporation, and low precipitation.[1]

Physiochemical and biological characteristics of representative reservoirs at the mine and east plant sites were sampled at least once during June to October, 1973. Sampling locations are shown in figures A-3 to A-5 and briefly described in table A-1. Existing data compiled by the Wyoming Game and Fish Commission were drawn upon for an inventory of fishes in streams of the Cheyenne River system.

2) Methods

a) Water Quality Analyses: Water quality data were obtained from on-site analyses of grab samples using a Hach Chemical Company portable field kit. Dissolved oxygen, total alkalinity, and total hardness were measured titrametrically; nitrate, sulfate, turbidity, and pH were measured photometrically (see table A-1 for results). Water temperature was measured with a standard chemical thermometer. Those chemical constituents not accurately measured in the field were analyzed from water samples collected on-site. Two one-gallon grab samples were collected per reservoir at the mine site and composited. One series of one-gallon samples was treated with sufficient hydrochloric acid to bring the pH down to approximately 2.0, thereby preserving them for later analysis of sodium, magnesium, calcium, and total organic carbon content. The second series was similarly treated with nitric acid for analysis of trace elements, including heavy metals. Results of those analyses are presented in table A-2.

b) Biological Analyses: Aquatic flora and fauna were sampled at selected reservoirs using recognized qualitative and quantitative techniques. Populations of zooplankton

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1 Culler, R. C. 1961. Hydrology of stock-water reservoirs in Upper Cheyenne River Basin. *In:* Hydrology of the Upper Cheyenne River Basin. U. S. Geol. Sur. Water-Supply Paper No. 53.

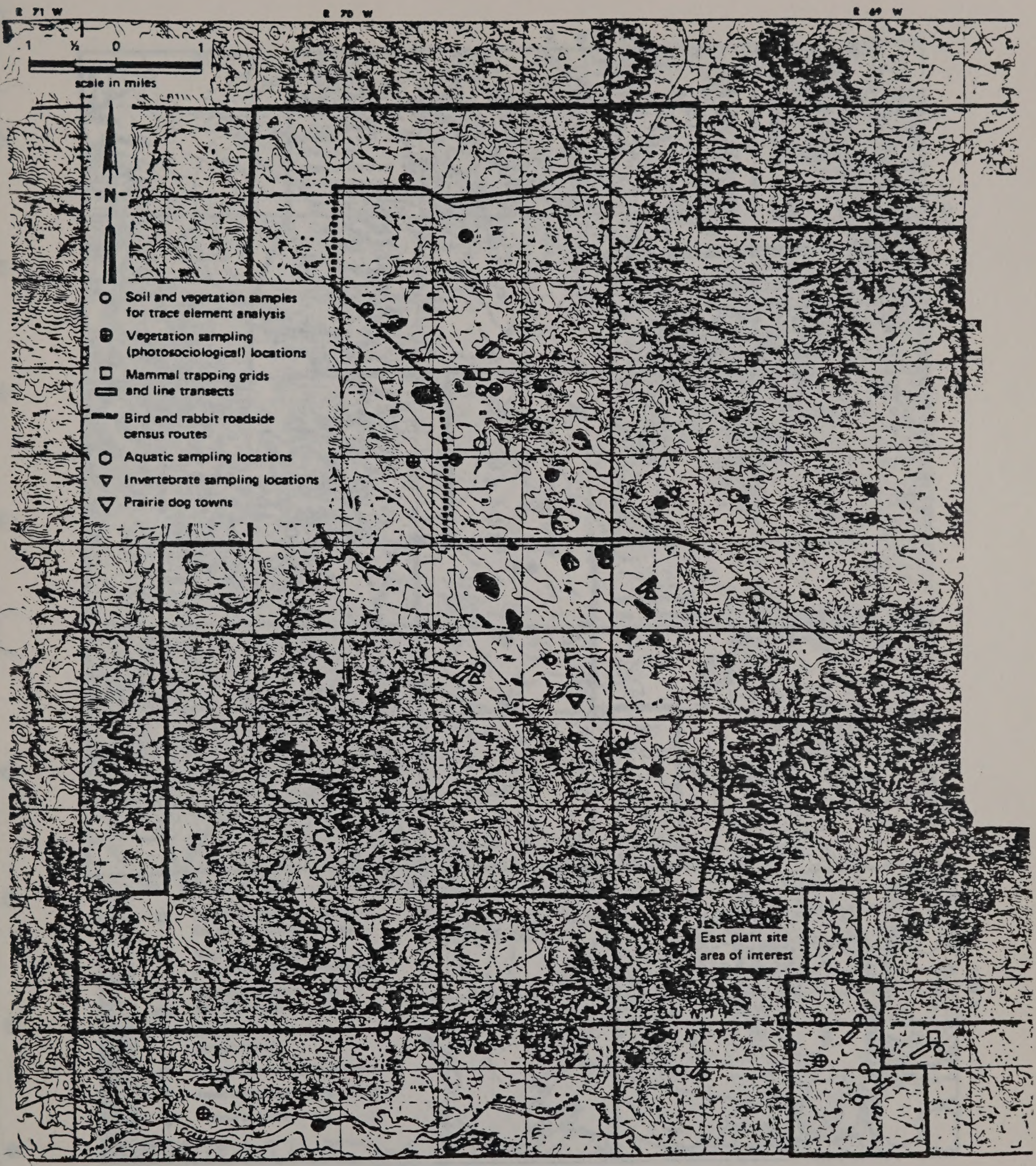

Figure A-3. Biological sampling locations on the Rochelle mine area keyed to the type of sampling performed and biological sampling locations on the east plant site.

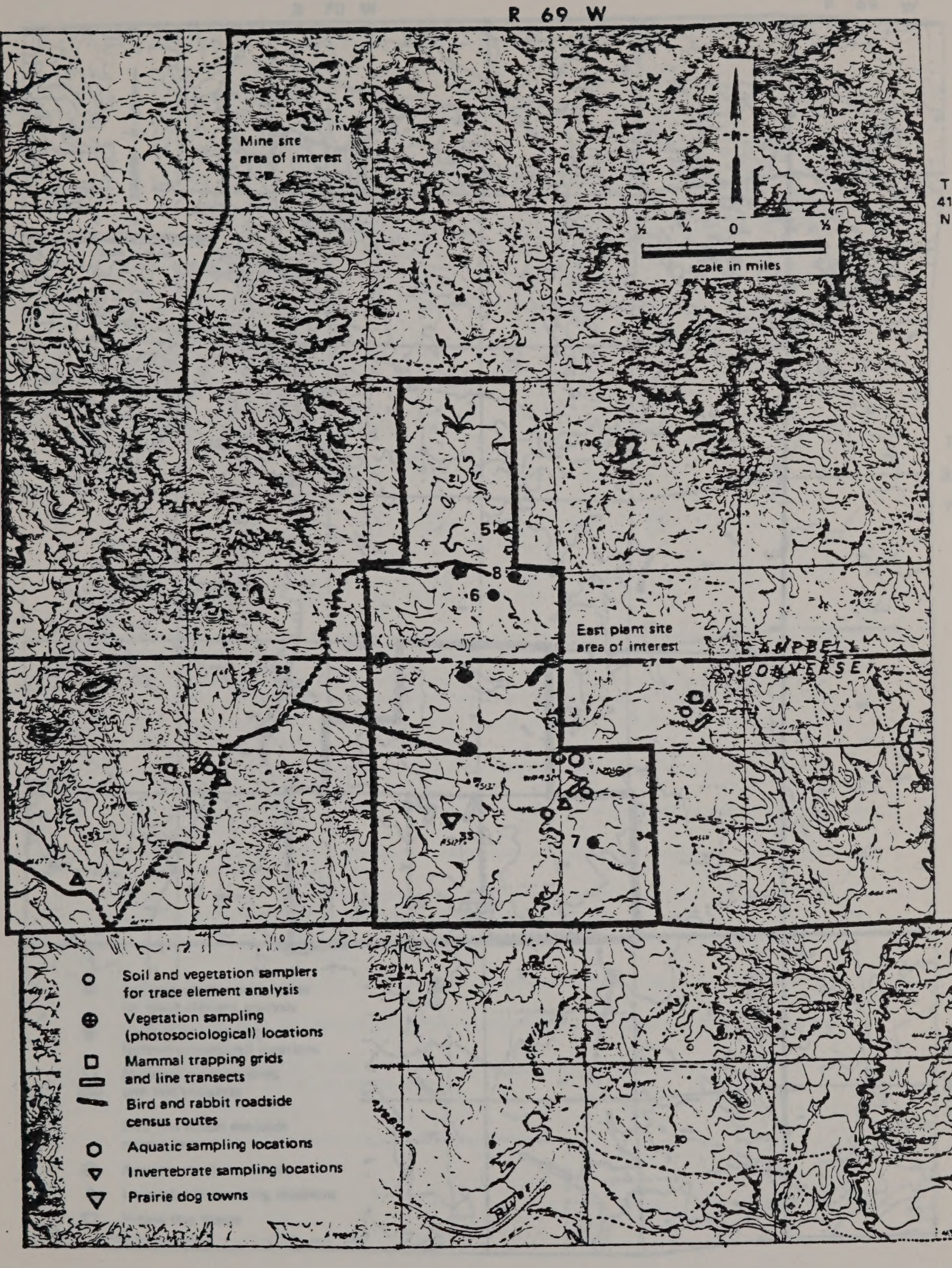

Figure A-4. Biological sampling locations on the east plant site.

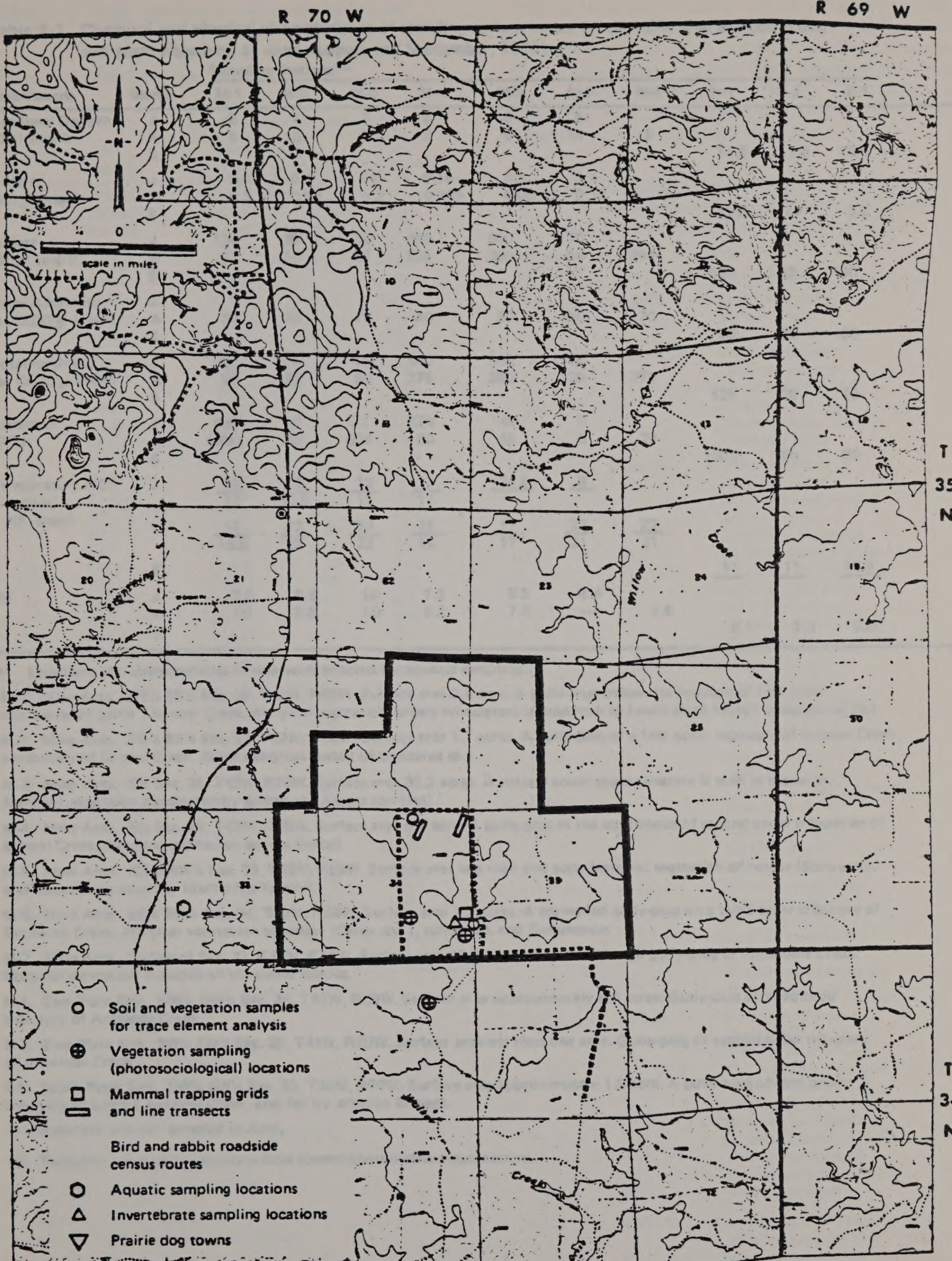

Figure A-5. Biological sampling locations on the south plant site.

Table A-1. Chemical and physical characteristics of standing surface water on the mine area and south and east plant sites (end of June, August and September, 1973).

Constituents	Month	M-1	M-2	M-3	M-4	M-5	M-6	M-8[b]	N-1	N-2	S-1
		Sampling Stations[a]									
Dissolved Oxygen	J	6	7	7	6	6	5				
(DO) (mg/l)	A	5	10	5	8	5	14	8			
	S								11.0	11.0	10.1
Nitrate	J	0.4	0.1	(c)	0.15	0.1	2.4				
(NO_3) (mg/l)	A	0.3	0.06	1.2	0.325	0.08	0.16	.04			
	S								12.0	--	2.0
Sulfate	J	124	35	30	460	300	70				
(SO_4) (mg/l)	A	81	18	27	625	300	54	294			
	S								520	52	100
Total Alkalinity	J										
(as $CaCO_3$) (mg/l)	A	30	75	70	40	60	80	70			
	S								30	20	30
Total hardness	J	82	105	55	440	305	165				
(as $CaCO_3$) (mg/l)	A	95	85	90	275	280	125	270			
	S								125	20	70
Turbidity	J	650	10	(c)	220	40	0				
(JTU)	A	1050	30	825	60	40	5	20			
	S								1000	185	20
Temperature (°C) surface	J	12	13	12	17	24.5	9				
10" depth	J	12	12.5	12	17						
surface	A	17	23	24	18	17	22	22			
10" depth	A	16.5	22	22	18	17	21	21			
surface	S								11	11	13.5
pH	J	7.0	8.6	(c)	7.3	8.5	8.4				
	A	(c)	9.8	(c)	8.2	7.5	--	8.6			
	S								6.1	7.3	9.8

(a) Locations and characteristics of reservoirs selected for aquatic sampling:

M-1. Mine Area. NE¼ SE¼ Sec. 34, T42N, R69W. Surface area 0.4 acre. A gully-plug below the juncture of first order tributaries of Little Thunder Creek. Marginal vegetation largely wheatgrass (*Agropyron* sp.) with some foxtail (*Alopecurus* sp.).

M-2. Mine Area. SW¼ SE¼ Sec. 23, T42N, R70W. Surface area 1.7 acres. A gully plug of a first order tributary of Holmes Creek, a tributary of School Creek. Some marginal foxtail (*Alopecurus* sp.)

M-3. Mine Area. E½ Sec. 35, T42N, R70W. Surface area 32.2 acres. A natural swale approximately ¼ mile in diameter. Marginal vegetation dominated by spikerush (*Juncus spartina*).

M-4. Mine Area. E½ Sec. 29, T42N, R69W. Surface area 0.7 acre. A gully-plug at the confluence of second order tributaries of School Creek. Marginal vegetation largely foxtail.

M-5. Mine Area. NE¼ NW¼ Sec. 33, T42N, R69W. Surface area less than one acre. Marginal vegetation of rushes (*Scirpus* sp.) and *Ranunculus aquatilis* (Buttercup family).

M-6. Mine Area. SE¼ SW¼ Sec. 34, T42N, R69W. Surface area 1.2 acres. A spring-fed gully-plug on a third order tributary of Beckwith Creek. Marginal vegetation of sedges (*Carex* spp.), spikerush, and *Ranunculus.*

M-7. Mine Area. Center of Sec. 27, T41N, R71W. Surface area 48.2 acres. A relatively large gully-plug of Porcupine Creek. Marginal vegetation included all the above species.

N-1. East Plant Site. NW¼ NW¼ Sec. 34, T41W, R69W. Surface area approximately 6.0 acres. Gully-plug of third order tributary of Antelope Creek.

N-2. East Plant Site. SW¼ SW¼ Sec. 28, T41N, R69W. Surface area less than one acre. Gully-plug of second order tributary of Antelope Creek.

S-1. South Plant Site. NW¼ SW¼ Sec. 33, T35N, R70W. Surface area approximately 1.0 acre. A gully-plug of first order tributary of Little Lightning Creek, also fed by artesian seepage.

(b) Reservoir was not sampled in June.

(c) Turbidity too high for accurate field spectrophotometric measurement.

Table A-2. Trace elements in water samples from all sampling locations and composited for the mine area and for south and east plant sites (summer, 1973)

Element no.	Element	Concentration, μg/ml[a] Mine area	East plant site	South plant site
1	Uranium	<.020	<.001	<.010
2	Thorium	<.100	<.010	<.010
3	Bismuth	.020	<.050	<.010
4	Lead	.090	.090	.080
5	Mercury	<.001	<.001	<.001
6	Osmium	<.060		<.020
7	Lanthanum	.027	.023	<.002
8	Barium	.020	.220	.007
9	Antimony	<.020	<.040	<.007
10	Tin	.540	1.000	<.010
11	Cadmium	.040	.040	<.005
12	Silver	<.020	<.030	<.006
13	Rhodium	<.010	<.020	<.003
14	Ruthenium	<.030	.050	<0.10
15	Molybdenum	.050	.033	.044
16	Strontium	.330	.310	.100
17	Selenium	.990	.050	<.010
18	Arsenic	.017	.011	.008
19	Germanium	<.030	.050	<.010
20	Gallium	.880	.150	.009
21	Zinc	.068	.300	.013
22	Copper	.500	.083	.080
23	Nickel	.030	.030	.005
24	Cobalt	.033	<.001	.007
25	Iron	9.800	7.500	.500
26	Manganese	.140	.270	.017
27	Chromium	.086	.067	.003
28	Vanadium	.140	.078	.002
29	Titanium	18.000	<10.000	<10.000
30	Calcium	17.000	48.000	15.000
31	Potassium	12.000	14.000	4.600
32	Chlorine	<1.000	3.500	2.500
33	Sulfur	18.000	58.000	25.000
34	Phosphorous	7.300	2.200	.360
35	Silicon	9.100	12.000	.930
36	Aluminum	54.000	16.000	1.000
37	Magnesium	9.200	24.000	5.800
38	Sodium	4.600	13.000	29.000
39	Fluorine	3.600	18.000	.330
40	Boron	1.300	2.100	.280
41	Beryllium	<.001	.001	<.001
42	Lithium		.076	.081

(a) Methods of analysis used by Accu-Labs, Wheat Ridge, Colorado.
Trace Elements — spark source mass spectrometry
Thorium — colorimetric spectrophotometry
Iron — atomic absorption
Titanium — ASTM colorimetric
Calcium — atomic absorption
Potassium — flame emission
Chloride (water) — volumetric
Sulfur (water) — gravimetric
Sulfur (soil, plants) — combusion columetric
Silicon — ASTM colorimetric
Aluminum — ASTM colorimetric
Magnesium — atomic Absorption
Sodium — flame emission
Fluorine — fusion colorimetric
Mercury — flameless atomic absorption

(minute animals—primarily passively floating or weakly swimming crustaceans and rotifers) were sampled with a cone-shaped 70 nm-mesh plankton net. The net was towed through the water and planktonic organisms were trapped in a receptacle at the base of the net. These samples were preserved in 5 percent formalin and transferred to the laboratory for identification (table A-3).

Table A-3. Zooplankton taxa identified from selected reservoirs on the mine area and south and east plant sites (July to October, 1973).

Sampling stations[a]	Date	Order *Genus species*
M-1	8/29/73	Rotifera (rotifers)
		Keratella valga
		Cladocera (water fleas)
		Daphnia schodleri
		Moina rectirostris
		Copepoda (copepods)
		Diaptomus clavipes
		Diaptomus coloradensis
		Eucyclops agilis
M-2	8/29/73	Rotifera (rotifers)
		Keratella valga
		Cladocera (water fleas)
		Bosmina coregoni
		Chydorus sphaericus
		Leydigia quadrangularis
		Pleuroxus trigonellus
		Copepoda (copepods)
		Diaptomus clavipes
		Diaptomus coloradensis
		Macrocyclops sp. (immatures)
M-3	8/29/73	Rotifera (rotifers)
		Conochilus sp.
		Cladocera (water fleas)
		Daphnia schodleri
		Moina rectirostris
		Copepoda (copepods)
		Diaptomus clavipes
		Diaptomus coloradensis
		Eucyclops agilis
M-4	8/29/73	Rotifera (rotifers)
		Conochilus sp.
		Keratella valga
		Cladocera (water fleas)
		Daphnia schodleri
		Moina rectirostris
		Copepoda (copepods)
		Diaptomus clavipes
		Diaptomus coloradensis
		Eucyclops agilis
M-5	7/6/73	Rotifera (rotifers)
		Brachionus sp.
		Cladocera (water fleas)
		Ceriodaphnia pulchella
		Chydorus sphaericus
		Simocephalus vetulus
		Copepoda (copepods)
		Acanthocyclops vernalis
		Diaptomus clavipes
		Diaptomus coloradensis
		Eucyclops agilis
M-6	8/29/73	Cladocera (water fleas)
		Chydorus sphaericus
		Copepoda (copepods)
		Acanthocyclops vernalis

(continued next page)

Sampling stations[(a)]	Date	Order / Genus species
M-7	8/30/73	Rotifera (rotifers)
		Keratella cochlearis
		Cladocera (water fleas)
		Alona guttata
		Chydorus sphaericus
		Scapholebris kingi
		Simocephalus vetulus
		Copepoda (copepods)
		Cyclops varicans rubellus
		Eucyclops prionophorus
N-1	9/29/73	Cladocera
		Daphnia sp.
		Copepoda
		Diaptomus sp.
N-2	9/29/73	Cladocera
		Bosmina sp.
		Daphnia spp.
		Copepoda
		Diaptomus sp.
S-1	10/1/73	Cladocera
		Daphnia sp.
		Copepoda
		Diaptomus spp.

(a) Locations and characteristics of aquatic sampling stations are given in table A-1.

Phytoplankton samples (planktonic algae, flagellates, and diatoms) were collected in the same manner. Results of the laboratory analyses of those samples are presented in tables A-4 and A-5.

Table A-4. Phytoplankton taxa identified from samples taken at station N-2 (September 1973)

Order / Genus species
Cyanophyta (Blue-green algae)
Microcystis sp.
Oscillatoria sp.
Chlorophyta (Green algae)
Golenkinia sp.
Coelastrum sp.
Chrysophyta (Golden-brown algae)
Mellomonas alpina
Bacillariophyta (Diatoms)
Cymbella sp.
Gyrosigma sp.
Stephanodiscus sp.
Navicula sp.
Fragilaria sp.

Table A-5. Phytoplankton taxa identified from samples taken at station S-1 (September 1973)

Order / Genus species
Cyanophyta (Blue-green algae)
Oedogonium sp.
Anabaena sp.
Oscillatoria sp.
Microcystis sp.
Chlorophyta (Green algae)
Chlamydomonas sp.
Scenedesmus bijuga
Spirogyra sp.
Elakatothrix viridis
Actinastrum hautschii
Cosmarium caelatum
Cosmarium triiobulatum
Closterium sp.
Pachycladon umbrinus
Sphaerocystis sp.
Eudorina sp.
Coelastrum sp.
Baccilariophyta (Diatoms)
Navicula sp.
Fragilaria sp.
Rhodopalodia sp.
Cymbella sp.

Benthic macroinvertebrates (bottom dwelling organisms—including molluscs, "worms," crustaceans, and immature insects) were collected from selected reservoirs with an Ekman dredge (a brass, spring-loaded, messenger-triggered device with a 0.25 sq. ft. frame). Bottom samples were obtained by lowering the dredge to the bottom of a body of water and triggering the release of "jaws" which enclose the contents within the frame. Two such samples were collected and composited, and results were expressed as organisms per square foot of bottom area. Opportunistic benthos sampling was often undertaken along selected shorelines ("grab samples" of table A-6). Such efforts consisted of hand and net capture of invertebrates observed and recognized as components of the benthic community during some stage of their life cycles. In this manner, insects which have a benthic stage as immatures were captured as adults. Two qualitative collections were obtained by dip netting when the dredge failed to operate. Benthos samples were preserved in 10 percent formalin solution and transferred to the laboratory for identification (table A-6).

Table A-6. Benthos taxa identified from selected reservoirs on the mine area and the south and east plant sites (July to October, 1973)

Sampling stations[a]	Date	Phylum: Class / Order / Family / Genus	Collection method	Number
M-2	6/20/73	Ectoprocta ("moss animals")		
		Phylactolaemata		
		Fredericellidae		
		Fredericella sp.	Grab	2
		Annelida: Oligochaeta (aquatic earthworms)		
		Plesopora		
		Tubificidae (sludge worms)		
		Tubifex sp.	Grab	1
		Annelida: Hirudinea (leeches)		
		Rhynchobdellida		
		Glossiphonidae ("snail leeches")		
		Placobdella sp.	Grab	20
		Mollusca: Gastropoda (snails)		
		Pulmonata ("lunged snails")		
		Planorbidae		
		Gyraulus sp.	Dredge	4/sq. ft.
		Arthropoda: Insecta (insects)		
		Ephemeroptera (mayflies)		
		Ametropidae		
		Ametropus sp.	Dredge	2/ sq. ft.
			Grab	4
		Caenidae		
		Caenis sp.	Grab	2
		Odonata (Zygoptera: damselflies)		
		Coenagrionidae		
		Ishnura sp.	Grab	22
			Dredge	10/sq. ft.
		Coleoptera (beetles)		
		Dytiscidae (predaceous diving beetles)	Grab	1
			Dredge	2/sq. ft.
		Diptera (true flies)		
		Chironomidae (midges)	Dredge	160/sq. ft.
M-6	6/22/73	Annelida: Hirudinea (leeches)		
		Rhynchobdellidae		
		Glassiphonidae ("snail leeches")		
		Helobdella sp.	Dredge	2/sq. ft.
		Mollusca: Gastropoda (Snails)		
		Pulmonata ("lunged snails")		
		Physidae		
		Physa sp.	Dredge	40/sq. ft.
		Planorbidae		
		Gyraulus sp.	Dredge	12/sq. ft.
		Mollusca: Pelecypoda (clams)		
		Heterodonta		
		Sphaeriidae (fingernail clams)		
		Musculium sp.	Dredge	22/sq. ft.
		Arthropoda: Insecta (insects)		
		Diptera (True flies)		
		Tabanidae (horsefly larvae)		
		Chrysops sp	Dredge	1/0.5 sq. ft.
	8/29/73	Ectoprocta ("moss animals")		
		Phylactolaemata		
		Plumatellidae		
		Plumatella sp.	Grab	2
		Annelida: Oligochaeta (earthworms)		
		Plesopora		
		Tubificidae (sludge worms)		
		Tubifex sp.	Dredge	2

(continued next page)

Sampling stations[a]	Date	Phylum: Class Order Family *Genus*	Collection method	Number
		Annelida: Hirudinea (leeches)		
		Rhynchobdellida		
		Glossiphonidae ("snail leeches")		
		Helobdella sp.	Grab	2
		Mollusca: Gastropoda (snails)		
		Pulmonata		
		Physidae		
		Physa sp.	Grab Dredge	3 2/sq. ft.
		Planorbidae		
		Gyraulus sp.	Grab Dredge	1 16/sq. ft.
M-2	8/29/73	Arthropoda: Insecta (insects)		
		Coleoptera (beetles)		
		Haliplidae (crawling water beetles)		
		Haliplus sp.	Dredge	2/sq. ft.
		Dytiscidae (predaceous diving beetles)		
		Dytiscus sp.	Dredge	14/sq. ft.
M-7	8/30/73	Annelida: Hirudinea (leeches)		
		Rhynchobdellidae		
		Glossiphonidae ("snail leeches")		
		Helobdella sp.	Dredge	8/sq. ft.
		Mollusca: Pelecypoda (clams)		
		Heterodonta		
		Sphaeriidae (fingernail clams)		
		Musculium sp.	Dredge	16/sq. ft.
		Mollusca: Gastropoda (snails)		
		Pulmonata ("lunged snails")		
		Physidae		
		Physa sp.	Dredge	6/sq. ft.
		Planorbidae		
		Gyraulus sp.	Dredge	6/sq. ft.
		Arthropoda: Insecta (insects)		
		Diptera (true flies)		
		Chironomidae (midges)	Dredge	2/sq. ft.
M-6	8/30/73	Mollusca: Gastropoda (snails		
		Pulmonata ("lunged snails")		
		Physidae		
		Physa sp.	Dredge	58/sq. ft.
		Planorbidae		
		Gyraulus sp.	Dredge	6/sq. ft.
		Mollusca: Pelecypoda (clams)		
		Heterodonta		
		Sphaeriidae (fingernail clams)		
		Musculium sp.	Dredge	6/sq. ft.
M-5	8/31/73	Mollusca: Gastropoda (snails		
		Pulmonata ("lunged snails")	Dredge	20/sq. ft.
		Arthropoda: Insecta (insects)		
		Ephemeroptera (mayflies)		
		Baetidae		
		Baetis sp.	Net	6
		Odonata: Zygoptera (damselflies)		
		Coenagrionidae		
		Ischnura sp.	Net	3
		Hemiptera (bugs)		
		Notonectidae (backswimmers)		
		Notonecta sp.	Net	1
		Diptera		
		Chironomidae (midges)	Net	1

(continued next page)

Sampling stations[a]	Date	Phylum: Class Order Family *Genus*	Collection method	Number
S-1	10/1/73	Mollusca: Gastropoda (snails)		
		Pulmonata ("lunged snails")		
		Planorbidae		
		Heliosoma sp.	Net	2
		Gyraulus sp.	Net	2
		Arthropoda: Insecta (insects)		
		Ephemeroptera (mayflies)		
		Ametrepidae		
		Ametropus sp.	Net	1
		Odonata: Zygoptera (damselflies)		
		Coenagrionidae		
		Ischnura sp.	Net	3
		Hemiptera (bugs)		
		Gerridae (water striders)		
		Gerris sp.	Net 1	1
		Coleoptera (beetles)		
		Hydrophilidae (water scavenger beetles)		
		Hydrophilus sp.	Net	1

(a) Locations and characteristics of aquatic sampling stations are given in table A-1.

Fish populations of the Cheyenne River Basin have been surveyed by the Wyoming Game and Fish Commission and their findings have been included in table A-7.[1]

b. Soils

The mine area includes a diversity of soil types ranging from extensive areas of Ulm or Renohill loam or clay loam (both categorized as fine, montmorillonitic, mesic Ustollic Haplargids) on the uplands to extensive areas of rough broken land with frequent outcrops of clinker material and parent rock but little soil development.[1,2] Numerous

1 Glassey, T. W., T. J. Dunnewald, J. Brock, H. H. Irving, N. Tippetss, and C. Rohrer. 1955. Soil survey (reconnaissance) of Campbell County, Wyoming. 1939 Series. No. 22. Soil Conservation Service, U. S. Dept. of Agric.

2 Soil Survey Staff, 1972. Soil series of the United States, Puerto Rico, and the Virgin Islands: their taxonomic classification. Soil Conservation Service. U. S. Dept. of Agric. 133 p.

Table A-7. Fishes known to occur within the Cheyenne River drainage[a]

Species	Stream of known occurrence	Species	Stream of known occurrence
Salmo gairdneri (Rainbow trout)	Stockade Beaver Creek Old Woman Creek Chip Creek	*Carpiodes carpio* (River carpsucker)	Cheyenne River
Salmo trutta (Brown trout)	Stockade Beaver Creek	*Catostomus commersoni* (White sucker)	Stockade Beaver Creek
Salvelinus fontinalis (Brook trout)	Hat Creek	*Catostomus platyrhynchus* (Mountain sucker)	Stockade Beaver Creek
Notemigonus crysoleucas (Golden shiner)	Stockade Beaver Creek	*Ictalurus melas* (Black bullhead)	Beaver Creek Crazy Woman Creek Cheyenne River
Hybopsis gracilis (Flathead chub)	Beaver Creek Little Thunder Creek Black Thunder Creek Cheyenne River	*Ictalurus punctatus* (Channel catfish)	Beaver Creek
		Fundulus sciadicus (Plains topminnow)	Crazy Woman Creek
Rhinichthys cataractae	Stockade Beaver Creek Beaver Creek	*Fundulus kansae* (Plains killifish)	Beaver Creek Black Thunder Creek Cheyenne River
Notropis stramineus missuriensis (Sand shiner)	Beaver Creek Little Thunder Creek Dry Fork Cheyenne River	*Lepomis cyanellus* (Green sunfish)	Beaver Creek Cheyenne River Little Thunder Reservoir, Campbell Co.
Hybognathus placitus (Plains minnow)	Beaver Creek Little Thunder Creek Black Thunder Creek Dry Fork Cheyenne River	*Lepomis macrochirus* (Bluegill)	Little Thunder Reservoir, Campbell Co.
		Etheostoma spectabile pulchellum (Orange throat darter)	Lodgepole Creek (possibly extinct here)
Pimephales notatus (Fathead minnow)	Beaver Creek Cheyenne River		

(a) Baxter, G. T. and J. R. Simon. 1970. Wyoming Fishes. Bull. No. 4. Wyo. Game & Fish Dept., Cheyenne, Wyo. 168 p.

small areas of soils in the Wibaux, McKenzie, and Searing series also occur within the mine area. The soil categories of the mine area and the east plant site are shown in table A-8 along with their usual topographic position and native vegetation. Unfortunately, there is no published soil survey information available for the south plant site vicinity in Converse County.

Soil and vegetation samples were taken from a variety of locations and retained for later compositing and chemical analyses. Sampling locations for the mine area, east plant site and south plant site are keyed on figures A-3, A-4, and A-5, respectively. These were selected to represent the existing range of slope steepness, slope direction and/or covering vegetation. Each soil sample was taken as a one-pound composite of material from three randomly located spots which were dug to 6 inches depth with a stainless steel trowel. Each plant sample consisted of one pound of plant material (roots and shoots) taken from the area corresponding to a soil sample. Table A-9 lists the location, slope steepness, slope aspect, and the predominant vegetative cover in the source area for each soil and vegetation sample collected. Table A-10 lists the results of standard chemical analyses on the same soil samples. Additionally, portions of all soil samples from the mine area and from the south and east plant sites were composited and analyzed for trace elements and heavy metals. Results are listed on table A-11. Table A-12 shows the results of chemical analyses performed on selected overburden corings from the mine site.

Table A-8. Soil classification, related topography and vegetation on the mine area and the east plant site

Series[a]	Texture	Classification[b]	Topographic position	Native vegetation
Ulm	loam or clay loam	fine, montmorillonitic, mesic Ustollic Haplargids	gently rolling uplands	sagebrush— grass
Renohill	loam, clay loam or clay	fine, montmorillonitic, mesic Ustollic Haplargids	gently to moderately rolling uplands and slopes	sagebrush — grass
Rough broken land	undifferentiated sandstone, shale, or limestone	not classified	dissected and severely eroded slopes	very sparse grasses and assorted shrubs
Renohill soil material	clay and shale	not classified	dissected and severely eroded slopes	barren or very sparse grasses and shrubs
Searing soil material	shale and clinker material	not classified	dissected and severely eroded slopes	barren to moderate cover of grasses and shrubs
Searing	gravelly loam	(probably similar to Wibaux below)	lower slopes and alluvial fans	dense sagebrush — grass
Wibaux	gravelly loam	loamy-skeletal over fragmental, mixed, nonacid mesic Ustic Terriorthents	slopes, knolls, and ridges	sparse sagebrush — grass
Arvada	sandy loam to clay loams	fine, montmorillonitic, mesic Ustollic Natrargids	drainage bottoms	salt and alkali tolerant grasses and shrubs (greasewood)
McKenzie	clay	not classified	upland playas	highly salt and alkali tolerant grasses, sedges, and forbs

(a) Glassey, T.W., T.J. Dunnewald, J. Brock, H.H. Irving, N. Tippetts, and C. Rohrer, 1955. Soil survey (reconnaissance) of Campbell County, Wyoming, 1939. Series, No. 22. Soil Conservation Service, U.S. Department of Agriculture.

(b) Soil Survey Staff. 1972. Soil series of the United States, Puerto Rico, and the Virgin Islands: their taxonomic classification. Soil Conservation Service, U.S. Department of Agriculture. 133 p.

Table A-9. Location and characteristics of the source area for each surface soil sample from the Rochelle mine and the south and east plant sites (1973)

Sample No.	Location	Slope	Azimuth	Source Area
	Rochelle Mine Area (late August)			
1	NE¼ NE¼ NE¼ Sec. 11, T41N, R69W	18°	063° (NE)	scattered ponderosa pine
2	"	20°	212° (SW)	"
3	NE¼ NW¼ NW¼ Sec. 2, T41N, R69W	16°	032° (NE)	rocky breaks
4	"	32°	243° (SW)	"
5	NE¼ NW¼ SW¼ Sec. 24, T42N, R70W	4°	308° (NW)	coal bed outcrop
6	"	4°	10° (N)	rushes, sedges and grasses
7	"	8°	068° (NE)	scattered sagebrush
8	NW¼ SW¼ NE¼ Sec. 23, T42N, R70W	2°	033° (NE)	scattered sagebrush
9	"	4°	222° (SW)	"
10	"	2°	144° (SE)	"
11	NE¼ NW¼ SE¼ Sec. 2, T41N, R70W	3°	238° (SW)	native and introduced grasses
12	"	0°	flat playa	"
13	SW¼ SW¼ Sec. 27, T42N, R69W	10°	278° (W)	sparse grasses and shrubs
14	NW¼ NW¼ Sec. 11, T41N, R70W	0°	(ridge top)	scattered sagebrush
15	"	13°	173° (S)	near coal bed outcrop
16	SW¼ SW¼ Sec. 10, T41N, R70W	6°	250° (SW)	scattered sagebrush
17	"	16°	130° (SE)	"
18	SW¼ NE¼ Sec. 9, T41N, R70W	0°	210° (SW)	scattered sagebrush
19	"	4°	304° (NW)	"
20	SW¼ SW¼ Sec. 31, T42N, R69W	3°	040° (NE)	dense sagebrush
21	SE¼ NW¼ Sec. 1, T41N, R70W	16°	320° (NW)	scattered sagebrush
22	SE¼ NW¼ Sec. 9, T41N, R70W	0°	—	greasewood and grasses
	(early December)			
23	NW ¼ Sec. 7, T41N, R69W	0°	—	scattered sagebrush
24	NE¼ Sec. 12, T41N, R70W	0°	—	scattered sagebrush
25	Center of E½ Sec. 30, T42N, R69W	5°	045° (NE)	scattered sagebrush
	East Plant Site (early October)			
26	NE¼ Sec. 31 & NW¼ Sec. 32, T41N, R69W	2°	240° (SW)	scattered ponderosa pine
27	"	8°	135° SE)	"
28	SE¼ Sec. 27, T41N, R69W	3°	257° (SW)	scattered sagebrush
29	"	1.5°	297° (NW)	"
30	Corner of Sec. 27, 28, 33, & 34, T41N, R69W	0°	(top of hill)	scattered sagebrush
31	SE¼ NE¼ Sec. 33, T41N, R69W	0°	—	grassy bottomland
32	SW¼ NW¼ Sec. , T41N, R69W	0°	(top of hill)	cottonwood bottomland
33	"	4°	280° (W)	"
34	SW¼ SE¼ Sec. 34, T35N, R60W	0°	small basin	scattered sagebrush
35	"	5°	106° (E)	"
36	NE¼ SE¼ SE¼ Sec. 34, T35N, R70W	6°	340° (N)	internal basin
37	"	3°	080° (E)	hayfield
38	NW¼ NW¼ NE¼ Sec. 34, T35N, R70W	6°	194° (S)	scattered sagebrush

Table A-10. Results of standard analyses performed on surface soil samples taken from the mine area and the south and east plant sites.[a]

Sample No.	pH	% Sand	% Silt	% Clay	% Organic matter	% moisture capacity, 15 bars	Conductivity, mmhos/cm	Sodium absorption ratio	Nitrate Nitrogen ppm	Phosphorous ppm	Available Potassium ppm	Cations meq/100 g soil Ca	Mg	Na	K	Cation Exchange Capacity
1	6.3	79	16	5	3.7	6.1	1.0	0.1	6	11	1500	8.0	1.0	1.4	2.9	22.6
2	6.5	74	18	8	3.0	7.6	1.8	0.2	8	13	900	8.8	1.1	1.4	1.7	17.4
3	6.6	45	45	10	5.0	9.4	2.7	0.3	13	7	455	9.4	1.2	1.2	0.8	18.7
4	6.5	48	44	8	5.7	8.4	2.6	0.1	21	30	600	8.8	1.2	1.1	1.1	19.1
5	4.5	39	23	38	7.2	26.2	4.6	0.1	7	1	700	8.6	1.1	1.0	1.4	57.0
6	4.3	41	24	35	10.0	25.3	18.0	0.2	3	2	345	6.8	0.7	8.3	0.5	58.3
7	6.5	57	16	27	2.0	18.3	2.1	0.5	5	1	205	9.0	1.2	0.9	0.3	12.2
8	6.3	55	28	17	2.2	12.6	1.5	0.1	4	11	292	9.0	1.3	0.7	0.4	9.6
9	6.9	69	21	10	2.0	8.5	2.1	0.2	8	27	308	9.2	1.3	0.4	0.5	9.1
10	6.4	49	28	23	3.7	16.5	2.5	0.3	15	70	700	9.0	1.0	1.9	1.3	19.1
11	6.2	53	31	16	1.9	11.9	1.1	0.2	7	20	280	10.0	1.3	0.4	0.5	11.3
12	5.5	48	31	21	2.6	15.0	1.0	0.2	10	242	500	9.8	1.3	1.0	1.0	18.7
13	6.4	35	35	30	1.7	20.0	2.1	0.3	7	7	210	9.8	1.1	2.6	0.4	13.9
14	7.2	53	26	21	1.8	14.8	3.2	0.1	8	13	292	9.0	1.3	0.3	0.4	10.9
15	6.9	81	9	10	1.2	8.2	1.4	0.2	3	1	132	10.0	1.0	0.4	0.2	5.9
16	6.2	44	46	10	4.0	9.0	1.4	0.1	11	50	700	9.8	1.4	0.4	1.1	13.5
17	6.7	65	29	6	4.6	6.9	2.6	0.1	16	54	650	10.0	1.4	0.4	0.9	14.8
18	7.1	24	30	37	3.2	24.5	5.2	0.2	12	1	428	8.0	1.2	0.8	0.7	21.8
19	7.4	53	29	18	2.5	14.0	3.1	0.1	8	3	260	8.0	1.4	0.3.	0.5	6.1
20	5.8	48	33	19	2.9	14.0	1.1	0.2	5	34	300	0.8	1.2	0.5	0.5	7.0
21	7.7	50	35	15	2.5	11.5	4.5	0.3	22	3	265	8.0	1.3	0.4	0.4	10.0
22	8.3	80	16	4	1.4	4.8	4.8	6.0	10	1	325	9.8	1.4	12.2	0.5	9.6
23	6.4	53	29	18	1.9	13.1	1.6	0.3	6	3	285	10.0	1.3	1.4	0.4	12.6
24	5.5	56	15	29	1.8	19.4	2.0	0.2	6	1	270	8.8	1.2	0.4	0.4	4.4
25	6.5	60	24	16	1.9	11.9	1.4	0.2	8	1	315	9.2	1.4	0.2	0.5	7.4
26	6.5	55	26	19	1.8	13.6	2.1	1.2	12	50	250	9.8	1.3	7.8	0.5	13.5
27	6.1	57	21	22	2.6	15.6	2.7	0.1	10	1	345	94.	1.3	0.4	0.6	7.8
28	6.2	63	21	16	3.1	12.3	2.1	0.1	13	3	285	9.2	1.3	9.7	0.5	10.0
29	6.7	69	19	12	2.1	9.7	2.9	0.1	11	37	650	8.8	1.4	0.3	0.8	13.9
30	7.1	64	18	18	2.0	13.1	3.5	0.2	8	2	428	8.8	1.3	0.2	0.7	11.3
31	5.2	61	18	21	1.8	14.8	1.4	0.1	2	0	130	9.2	1.4	0.3	0.2	11.3
32	5.6	72	16	12	1.8	9.6	1.0	0.1	2	0	100	10.0	1.4	0.3	0.2	13.5
33	7.5	42	25	33	2.7	22.0	4.8	0.7	3	0	165	8.0	1.1	2.9	0.3	10.0
34	6.4	42	34	24	3.4	17.0	2.8	0.1	11	21	438	8.8	1.3	0.3	0.7	6.1
35	6.4	67	16	17	4.1	13.1	2.1	0.1	9	34	950	9.0	1.4	0.3	1.5	14.8
36	7.5	37	35	28	2.7	19.1	5.2	0.3	6	24	460	8.8	1.3	9.6	0.7	14.4
37	6.5	81	12	7	1.9	6.7	1.4	0.1	4	9	232	9.4	1.5	0.2	0.4	10.4
38	6.9	92	3	5	2.1	5.6	2.2	0.1	2	2	175	9.4	1.4	0.4	0.3	10.4

(a) The locations and characteristics of sou.ce areas for the above areas are listed in table A-8.

Table A-11. Trace elements and heavy metals in a composite of all soils from the mine area and from the south and east plant sites

Element No.	Element	Concentration (% dry weight or ppm, dry basis[a]) Mine Area	East Plant Site	South Plant Site
1	Uranium	3.	3.1	3.,1
2	Thorium	7.9	7.	7.9
3	Bismuth	1.1	2.1	<.35
4	Lead	18.	18.	36.
5	Mercury	0.11	<.03	0.06
6	Osmium	<.1	<.10	<.10
7	Lanthanum	3.3	3.3	4.9
8	Barium	770.	470.	630.
9	Antimony	0.7	5.5	0.32
10	Tin	2.2	0.8	0.8
11	Cadmium	0.87	0.87	0.86
12	Silver	0.18	0.34	0.18
13	Rhodium	<.10	<.10	<.10
14	Ruthenium	<.10	<.10	<.10
15	Molybdenum	4.2	150.	2.6
16	Strontium	130.	4.5	85.
17	Selenium	0.81	0.38	0.63
18	Arsenic	3.7	1.5	5.3
19	Germanium	0.85	0.85	0.59
20	Gallium	8.1	8.1	8.1
21	Zinc	38.	38.	45.
22	Copper	27.	49.	17.
23	Nickel	1.6	1.6	3.4
24	Cobalt	2.2	2.2	4.5
25	Iron	1.60%	1.3%	1.6%
26	Manganese	81.	81.	100.
27	Chromium	13.	13.	48.
28	Vanadium	25.	30.	37.
29	Titanium	3000.	5700.	1200.
30	Calcium	0.4%	0.23%	0.42%
31	Potassium	1.7%	1.6%	1.7%
32	Chlorine	100.	100.	86.
33	Sulphur	0.13%	810.	0.08%
34	Phosphorous	270.	270.	3400.
35	Silicon	37.1%	38.4%	36.3%
36	Aluminum	3.2%	2.7%	3.0%
37	Magnesium	0.27%	0.16%	0.26%
38	Sodium	2800.	1500.	7300.
39	Fluorine	650.	650.	650.
40	Boron	71.	39.	25.
41	Beryllium	1.2	1.6	3.6
42	Lithium	47.	47.	72.

(a) Methods of analysis used by Accu-Labs, Wheat Ridge, Colorado, are listed in table A-2.

c. Vegetation

Native vegetation on the Rochelle mine and the south and east plant sites is primarily a mixture of grasses and sagebrush. Sagebrush density varies according to local soil conditions and is replaced by greasewood or other more salt-tolerant shrubs in saline bottomlands or upland playas. The principal grasses are western wheatgrass (*Agropyon spicatum*) and blue grama grass (*Bouteloua gracilis*), although other species may predominate in localized areas. Some portions of the three sites have been under cultivation and subjected to differential grazing intensities; this history is reflected in the existing vegetation composition and coverage.

1) Methods

The major vegetation types in the vicinities of the mine and the two plant sites were determined during reconnaissance surveys. Because the mine lease covers such a large area, involving four townships in the southeast corner of Campbell County, it was deemed important that some estimate of the coverage by each vegetation type be obtained. This was done for each of the four townships with the aid of Forest Service vegetation maps for the area. The resulting rough estimates are listed in table A-13. Within each vegetation type representative sampling sites were selected in a stratified random fashion to obtain adequate coverage throughout each of the three areas. Locations sampled within each vegetation type are listed in table A-14 and are shown in figures A-3-A-5. The number of sites within a given vegetation type reflects the preponderance of that type in the area.

At each sampling site three 100-foot belt transects were employed to determine the percent of ground covered by shrub and cactus species (line intercept method).[1,2] Results for all three areas are listed in table A-15. Superimposed on each belt transect were 5 quadrats, each 4 feet square in size, within which an ocular estimate was made of the percent cover by each plant species. The first quadrat was located 10 feet from the beginning of the belt transect and the remaining quadrats were placed at 20 feet intervals beyond that point. Vegetation composition was determined within each major type by compiling the percent cover of each perennial plant species that contributed enough cover (at least 0.5 percent at one or more sampling locations) to be included in the calculations. Statistics on vegetation composition thus obtained at the Rochelle mine are recorded in table A-16, statistics for the east and south plant sites are recorded in tables A-17 and A-18, respectively. For the mine area, all such species, plus those species which never covered as much as 0.5 percent of the ground and other species recorded during reconnaissance are presented in a composite species list (table A-19).

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1 Canfield, R. H. 1941. application of the line interception method in sampling range vegetation. Jour. Forestry 39:388-394.

2 National Academy of Sciences. 1962. Basic problems and techniques in range research. National Academy of Sciences—National Research Council. Publication No. 890. 342 p.

Table A-12. Selected results of chemical analyses on several overburden corings from the Rochelle mine

Depth (feet)	Lithology	Thickness (feet)	pH	% dry sulfur	$CaCO_3$ Equivalent[(a)]	Salt Hazard[(b)]	Sodium, ppm
Drill hole 172C							
1.0	claystone	4.5	7.2	.36	11.11	12.5	592
5.5	clay and sandstone	2.5	4.2	.46	15.69	15.0	752
7.0	claystone	3.0	4.0	.20	7.32	8.3	460
10.0	sandstone	5.0	3.7	.05	3.28	3.5	128
15.0	siltstone	3.5	3.6	.10	5.15	7.5	190
18.5	siltstone	2.7	4.2	.02	1.83	2.1	176
74.0	siltstone	7.0	8.5	.02	.60	1.1	272
81.0	siltstone	5.5	8.3	.01	---	.9	386
Drill hole 527C							
60.4	sandstone	1.8	8.1	.32	8.26	.6	122
62.2	thin coal	.8	7.3	2.54	58.46	2.3	572
64.5	sandstone	1.7	7.3	.52	14.69	.8	144
70.0	thin coal	.1	6.2	3.00	79.01	3.0	684
86.0	thin coal	.4	6.8	.84	4.76	1.0	656
90.0	shale	1.2	6.7	.78	13.79	1.5	492
91.2		.9	6.8	.75	18.75	.8	526
Drill hole 723C							
2.0	sandstone	8.5	8.0	.48	---	16.0	480
10.5	shale, sandstone	7.5	7.7	.83	---	17.0	760
18.0	sandstone, shale	5.0	6.1	.92	2.36	16.0	360
23.0	shale, quartzite	10.0	3.7	.55	18.79	15.0	460
33.0		4.0	5.9	.73	11.46	3.4	906
60.0	shale, coal	7.0	5.7	.69	5.65	3.6	600
121.0	sandstone, shale	13.8	6.2	.34	5.83	2.1	150
Drill hole 771C							
0.0	surface sand-clay	7.0	5.0	.34	5.74	13.5	640
7.0	shale, sandstone	6.0	3.7	.24	---	7.8	220
13.0	shale	3.0	3.8	.41	13.50	11.0	260
40.0	coal, dark shale	3.0	5.4	1.06	14.04	3.6	120
114.5	dark siltstone	16.0	7.9	4.35	128.20	1.8	200
Drill hole 763C							
0.0	humus, clay	2.0	4.5	.13	---	6.2	204
13.5	thin coal	.5	5.3	3.23	81.26	3.4	488
23.0	shale, coal	2.0	5.8	2.51	61.60	7.0	576
100.5	coal, shale	1.0	6.3	.11	---	2.0	886
114.5	thin coal	1.0	8.2	.56	.06	.6	884

(a) Tons of $CaCO_3$ equivalent per 1000 tons of material needed for neutrality. An amount in excess of 5.0 is considered to be toxic and should not be placed on the surface.

(b) Measured in mmhos/cm: 2-4 is considered slightly saline, 4-8 is moderately saline and 8-16 is strongly saline with regard to agricultural crops. Only salt tolerant species can persist at higher levels of salinity.

Table A-13. The percentages of four townships encompassing the Rochelle mine which were covered by each major vegetation type

Townships	Vegetation Type: Rough breaks	Heavy sagebrush	Scattered sagebrush	Grass-land	Other
T42N, R69W	70	3	16	10	1[(a)]
T41N, R69W	55	3	30	12	0
T42N, R70W	17	3	63	16	1[(b)]
T41N, R70W	69	1	10	17	3[(c)]
Total Area	52.8	2.2	28.6	14.6	1.7

(a) Range seeding.

(b) Abandoned farmland.

(c) Cottonwood and greasewood bottomland.

Table A-14. Locations at which vegetation composition and coverage were sampled for each vegetation type on the mine area (July, 1973) and on the south and east plant sites (October, 1973)

Number of samples	Vegetation Type: Rough breaks	Heavy sagebrush	Scattered sagebrush	Grassland	Bottomland and other
Mine Area					
1	S20 T42N R69W	S26 T42N R70W	S7 T41N R69W	S6 T41N R69W	S33 T41N R70W
2	S13 T42N R70W	S11 T42N R70W	S23 T42N R70W	S28 T42N R69W	S32 T42N R70†
3	S26 T42N R69W	S36 T42N R70W	S27 T42N R69W	S15 T42N R70W	S27 T41N R70W
4	S17 T42N R69W		S4 T41N R69W	S8 T41N R70W	
5	S12 T41N R70W		S3 T42N R70W		
6	S10 T41N R70W		S25 T42N R70W		
7	S9 T41N R70W				
8	S30 T42N R69W				
East Plant Site					
1		SW¼ S27 T41N R69W	NE¼ S28 T41N R69W		NE¼ S33 T41N R69W (grassy floodplain)
2			SE¼ S28 T41N R69W		
3			SW¼ S28 T41N R69W		
South Plant Site					
1		NE¼ S35 T34N R70W	SE¼ S35 T34N R70W		NW¼ S2 T34N R70W (hayfield)

Table A-15. Average percent of belt transects intercepted by shrub or cactus species on the mine area and the south and east plant sites

Species	Vegetation Type: Rough breaks	Heavy sagebrush	Scattered sagebrush	Grass-land	Bottomland
Mine Area					
Artemisia cana (silver sagebrush)	0.3				0.9
Artemisia tridentata (big sagebrush)	3.6	20.1	5.4	0.3	
Sarcobatus verimiculatus (black greasewood)					4.4
Opuntia polyacantha (plains pricklypear)	0.4	0.4	1.6	0.3	0.1
East Plant Site					
Artemisia tridentata			6.4		0
Opuntia polyacantha			2.6		0
South Plant Site					
Artemisia tridentata		2.2	5.2		
Opunta polyacantha		0.2	0		

Table A-16. Average percent of quadrat cover by perennial plant species within the major vegetation types on the mine area.

Species	Rough breaks	Heavy sagebrush	Scattered sagebrush	Grass-lands	Scattered greasewood	Creek bottom
	Vegetation type					
Grasses						
Agropyron smithii (western wheatgrass)	1.4 ±0.7[a]	2.2 ±0.9	3.1 ±1.0	3.8 ±2.5	0.6 ±1.0	1.9 ±2.5
Agropyron spicatum (bluebunch wheatgrass)	0.1					T
Agrostis sp. (bent)					0.3	
Andropogon scoparius (little bluestem)	0.1					
Aristida longiseta (red threeawn)	1[b]					
Bouteloua gracilis (blue grama)	9.5 ±4.0	2.9 ±2.5	8.3 ±4.0	15.1 ±10.4	5.2 ±3.9	0.3 ±1.1
Calamovilfa longifolia (prairie sandreed)	0.7					5.3
Elymus sp. (wildrye)	0.6		T			
Hordeum jubatum (foxtail barley)					T	
Koeloria cristata (prairie junegrass)	0.2	2.1	1.2	0.5		
Oryzopsis hymenoides (Indian ricegrass)						0.2
Phleum pratense (common timothy)	0.1					
Poa secunda (Sandberg bluegrass)	0.2	0.4	0.6	0.8	0.4	
Poa spp. (bluegrass)	0.3			T		0.2
Schedonnardus paniculatus (common tumblegrass)	T	T		0.6		
Stipa comata (needle-and-thread grass)	0.8	0.4	1.4	1.0		2.3
Stipa viridula (green needlegrass)	0.1	0.4	T			
Total Perennial Grasses	13.9 ±3.4	8.4 ±2.1	14.7 ±4.13	21.6 ±8.3	6.5 ±4.2	10.4 ±9.7

(continued next page)

Species	Vegetation type: Rough breaks	Heavy sagebrush	Scattered sagebrush	Grass-lands	Scattered greasewood	Creek bottom
Forbs						
Achillea lanulosa (western yarrow)			0.1			
Antennaria rosea (rose pussytoes)	0.1	T				
Arenaria hookeri (Hooker sandwort)	0.1	T	0.1			
Astragalus spp. (milkvetch)	T		T	T		
Carex eleocharis (needleleaf sedge)	0.1	0.2	0.3	0.7		0.1
Carex filifolia (threadleaf sedge)	0.7	0.3	0.4	0.8		
Commandra pallida (bastard toadflax)	T					T
Erigeron pumilus (low fleabane)	T	T	T	T		
Eurotia lanata (winterfat)	0.1	0.1	T	T		
Grindelia squarrosa (curlycup gumweed)	T				0.1	
Gutierrezia sarothrae (broom snakeweed)	0.2	0.2	0.2	0.1		
Phlox hoodii (Hoods phlox)	0.2	0.1	0.2	0.2		
Psoralea tenuiflora (slimflower scurfpea)						0.2
Sphaeralcea coccinea (scarlet globemallow)	0.1	0.1	0.1	0.1		
Taraxacum officinale (dandelion)	T				0.1	
Tragopogon dubius (yellow salsify)			T			T
Trifolium spp. (clover)	T					
Vicia linearis (vetch)	0.1	0.1	T	0.1		
Miscellaneous Forbs	0.4	0.1	0.1	0.1	0.2	0.8
Total Perennial Forbs	2.2 ±0.7	1.2 ±1.0	1.6 ±1.0	2.2 ±1.5	0.4 ±0.4	1.2 ±3.3

(continued next page)

Species	Vegetation type: Rough breaks	Heavy sagebrush	Scattered sagebrush	Grass-lands	Scattered greasewood	Creek bottom
Lichens	0.4	0.7	0.7	1.2		
Shrubs and Cat						
Lichens	0.4	0.7	0.7	1.2		
Shrubs and Cactus						
Artemisia cana (silver sagebrush)	T					0.7
Artemisia frigida (fringed sagebrush)	0.5	0.9	0.7	0.7		0.3
Artemisia tridentata (big sagebrush)	2.5 ±2.0	15.6 ±4.6	5.5 ± 2.0	0.1		
Atriplex canescens (fourwing saltbush)	T					
Chrysothamnus nauseosus (rubber rabbitbrush)	T					
Eriogonum multiceps (wild buckwheat)	T					
Mamillaria vivipara (pincushion cactus)	T			T		
Opuntia polyacantha (plains prickly pear)	0.4	0.6	2.0	0.2		
Sarcobatus vermiculatus (black greasewood)					2.6	
Total Perennial Shrubs	3.5 ±1.9	17.1 ±4.3	8.2 ±2.3	1.0 ±1.4	2.6 ±3.3	1.0 ±2.9
Total Perennial Species(c)	19.6 ±4.8	26.7 ±4.6	25.0 ±3.5	24.8 ±7.5	9.3 ±4.8	12.2 ±10.0

(a) 95% confidence intervals for dominant species and life form totals.

(b) T = trace. Species which average 0.01 to 0.05 percent cover for all sampling locations within a vegetation type. They may be of localized importance.

(c) Total species as used here is the summation of cover by the three life forms listed and does not account for overlap of grasses and forbs beneath the shrub canopy.

Table A-17. Average percent of quadrat cover by perennial plant species within the major vegetation types on the east plant site

Quadrat Cover Species	Vegetation Type: Scattered Sagebrush	Bottomland
GRASSES		
Agropyron smithii (western wheatgrass)	2.0 ±0.8	28.3
Aristida sp. (threeawn)		0.2
Bouteloua gracilis (blue grama)	17.1 ±5.0	
Bromus inermis (smooth brome)		0.4
Koeleria cristata (plains junegrass)	0.4	
Poa secunda (sandberg bluegrass)	0.3	T
Schedonnardus paniculatus (common tumblegrass)	T	
Stipa comata (needle-and-thread)	1.0	
Total Perennial Grasses	20.6 ±4.7	29.0

Quadrat Cover Species	Vegetation Type: Scattered Sagebrush	Bottomland
FORBS AND LICHENS		
Astragalus sp. (milk vetch)	T	
Carex filifolia (threadleaf sedge)	0.5	
Carex nebraskensis (nebraska sedge)		0.2
Erigeron pumilus (low fleabane)	0.1	
Grindelia squarrosa (curlycup gumweed)		0.1
Gutierrezia sarothrae (broom snakeweed)	0.2	
Lomatium sp. (desert parsely)	T	
Phlox hoodii (Hood's phlox)	0.1	
Sphaeralcea coccinea (scarlet globemallow)	T	0.1
Taraxacum officinale (dandelion)		0.8
Vicia sp. (vetch)	T	
Lichens	0.8	
Total perennial forbs and lichens	1.8 ±1.6	1.4

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Quadrat Cover Species	Vegetation Type: Scattered Sagebrush	Vegetation Type: Bottomland
SHRUBS AND CACTUS		
Artemisia frigida (fringed sagebrush)	0.7	
Artemisia tridentata (big sagebrush)	6.8 ±4.3	
Opuntia polyacantha (plains pricklypear)	6.6	
Total perennial shrubs	14.2 ±4.4	
Total perennial species	36.6	30.4

Table A-18. Average percent of quadrat covered by perennial plant species within the major vegetation types on the south plant site

Quadrat Cover Species	Vegetation Type: Heavy sagebrush	Scattered sagebrush	Hayfield
GRASSES			
Agropyron cristatum (crested wheatgrass)	1.0		19.1±14.2
Agropyron smithii (western wheatgrass)	2.8±1.7	0.9	
Aristida longiseta (red threeawn)		10.7 ±16.6	1.1
Bouteloua gracilis (blue grama)	12.3 ±8.2	0.7	
Koeleria cristata (prairie junegrass)	0.9	T	
Poa secunda (sandberg bluegrass)	2.4		0.2
Schedonnardus paniculatus (common tumblegrass)	0.4		0.3
Stipa comata (needle-and-thread)	0.7 ±0.8	6.2 ±15.5	
Total perennial grasses	20.4±7.2	18.5 ±25.2	20.6 ±15.4
FORBS AND LICHENS			
Arenaria hookeri (hooker's sandwort)	0.1		
Astragalus sp. (milk vetch)	0.1	0.2	
Carex filifolia (needleleaf sedge)	1.8		
Grindelia squarrosa (curlycup gumweed)			0.3
Gutierrezia sarothrae (broom snakeweed)	0.2	0.6	
Lesquerella stenophylla (mountain bladderpod)	T		
Phlox hoodii (Hood's phlox)	0.1		
Sphaeralcea coccinea (scarlet globemallow)	0.1	0.5	0.1
Taraxacum officinale (dandelion)			0.1
Tragopogon dubius (yellow salsify)		0.4	
Trifolium incarnatum (alsike clover)			0.1
Lichens	1.7	T	
Total perennial forbs and lichens	3.2 ±1.3	1.8 ±1.4	1.6 ± 2.8
SHRUBS AND CACTUS			
Artemisia frigida (fringed sagebrush)	0.1	3.4 ±8.8	0.1
Artemisia tridentata (big sagebrush)	4.5 ±3.0	4.3 ±16.0	
Opuntia polyacantha (plains pricklypear)	0.5		
Total perennial shrubs and cactus	5.1±3.0	7.7 ±11.8	0.1
Total perennial species	28.8	28.0	22.3

Table A-19. Species list for the Rochelle mine and adjacent land (summer, 1973)

Scientific name	Common name
Achillea lanulosa	western yarrow
Agoseris glauca	pale agoseris
Agropyron cristatum	crested wheatgrass
Agropyron intermedium	intermediate wheatgrass
Agropyron smithii	western wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Agropyron spp. (intro.)	wheatgrass
Agrostis spp.	bent
Allionia glandulifera	prairie allionia
Allium reticulatum	prairie onion
Allium textile	prairie onion
Andropogon scoparius	little bluestem
Anogra violacea	violet anogra
Antennaria dimorpha	low pussytoes
Antennaria rosea	rose pussytoes
Arenaria hookeri	Hooker sandwort
Aristida longiseta	red threeawn
Arnica fulgens	orange arnica
Artemisia cana	silver sagebrush
Artemisia frigida	fringed sagebrush
Artemisia gnaphalodes	cudweed sagewort
Artemisia pedatifida	birdfoot sagebrush
Artemisia tridentata	big sagebrush
Astragalus spp.	milk vetch or loco
Astragalus caespitosus	milk vetch or loco
Astragalus purshii	Pursh locoweed
Atriplex canescens	fourwing saltbush
Bouteloua gracilis	blue grama
Bromus japonicus	Japanese brome
Bromus tectorum	chestgrass brome
Calamovilfa longifolia	prairie sandreed
Carex eleocharis	needleleaf sedge
Carex filifolia	threadleaf sedge
Carex spp.	sedge
Cerastium arvense	starry cerastium
Chenopodium album	lambsquarters goosefoot
Chrysopsis spp.	golden aster
Chrysothamnus nauseosus	rubber rabbitbrush
Cirsium spp.	thistle
Comandra pallida	bastard toadflax
Cryptantha bradburiana	miner's candle cryptantha
Distichlis spicata	inland saltgrass
Elymus cinereus	basin wildrye
Erigeron pumilus	low fleabane
Eriogonum multiceps	wild buckwheat
Euphorbia serpens	spurge
Eurotia lanata	winterfat
Gaura glaber	gaura
Grindelia squarrosa	curlycup gumweed

(continued next page)

Scientific name	Common name
Gutierrezia sarothrae	broom snakeweed
Helianthus annuus	common sunflower
Hordeum jubatum	foxtail barley
Juncus balticus	baltic rush
Kochia scoparia	fireweed summercypress
Koeleria cristata	prairie junegrass
Lappula occidentalis	western stickseed
Lepidium spetalum	pepperweed
Lesquerella argentea	silver bladderpod
Lesquerella stenophylla	mountain bladderpod
Leucocrinum montanum	common starlily
Lewisia rediviva	bitterroot lewisia
Lupinus spp.	lupine
Lygodesmia juncea	rush skeletonplant
Malvastrum coccineum	falsemallow
Mammillaria vivipara	purple pincushion cactus
Melilotus officinalis	yellow sweetclover
Oenothera caespitosa	tufted evening primrose
Oonopsis argillocea	no common name
Opuntia polyacantha	plains prickly pear
Oryzopsis hymenoides	Indian ricegrass
Parmelia spp.	parmelia (lichen)
Penstemon albidus	white penstemon
Petalostemon candidum	white prairieclover
Phleum pratense	timothy
Phlox glabrata	phlox
Phlox hoodii	Hoods phlox
Pinus ponderosa	ponderosa pine
Plantago purshii	woolly plantain
Poa canbyi	canby bluegrass
Poa fendleriana	mutton bluegrass
Poa secunda	Sandberg bluegrass
Poa spp.	bluegrass
Populus sargenti	plains cottonwood
Psoralea esculenta	common breadroot scurfpea
Psoralea tenuiflora	slimflower scurfpea
Rhus trilobata	skunkbush sumac
Rosa woodsii	woods rose
Salix spp.	willow
Salsola kali	common Russian thistle
Salsola pestifer	tumbleweed Russian thistle
Sarcobatus vermiculatus	black greasewood
Schedonnardus paniculatus	common thumblegrass
Sideranthus grindeloides	gumweed sideranthus
Sideranthus spinulosus	spiny sideranthus
Sphaeralcea coccinea	scarlet globemallow
Sporobolus airoides	alkali sacaton
Sporobolus cryptandrus	sand dropseed
Stipa columbiana	subalpine needlegrass
Stipa comata	needle-and-thread
Stipa viridula	green needlegrass
Taraxacum officinale	common dandelion
Thermopsis spp.	thermopsis
Thermopsis montana	mountain thermopsis
Tradescantia occodentalis	prairie spiderwort
Tragopogon dubius	yellow salsify
Trifolium spp.	clover
Vicia linearis	vetch
Vulpia octoflora	common sixweeksgrass
Yucca glauca	small soapweek
Zigadenus venenosus	meadow deathcamas

In addition, one-pound vegetation samples (roots and shoots) were collected in conjunction with soil samples as described in the section on soils. The vegetation was freed of soil particles, ground to 60 mesh and composited for trace element analyses (including heavy metals). The results of those analyses are listed in table A-20.

Table A-20. Trace elements and heavy metals in selected vegetation samples composited from the mine area (August, 1973) and the south and east plant sites (September, 1973)

		Concentrations (% dry weight or ppm, dry basis) of Composites[(a)]								
		Mine Area					East Plant Site		South Plant Site	
Element No.[(b)]	Element	1	2	3	4	5	6	7	8	9 1/
1	Uranium	.18	.36	.39	.18	.18	.78	.18	.37	.10
2	Thorium	4.7	7.0	5.6	4.5	6.3	4.6	5.5	8.4	3.6
3	Bismuth	.091	.24	.68	.08	.11	.19	.09	<.11	<.16
4	Lead	5.0	4.4	7.4	2.4	3.1	6.12	1.5	7.1	3.0
5	Mercury	.05	.04	<.03	<.03	.10	<.03	.05	<.03	<.03
6	Osmium	<.29		<.27	<.27	<.26	<.26	<.26	<.27	<.27
7	Lanthanum	54.	68.	60.	16.	77.	42.	34.	46.	19.
8	Barium	420.	260.	690.	200.	270.	270.	73.	370.	270.
9	Antimony	.49	1.4	<.60	<.60	<.59	<.59	<.59	<.60	<.60
10	Tin	8.2	7.9	4.3	<.40	7.8	<.40	<.40	5.3	<.40
11	Cadmium	.082	.08	.28	.04	.02	.03	.01	.03	.008
12	Silver	1.3	2.0	<.66	<.66	2.6	<.66	<.66	<.66	<.66
13	Rhodium	<.04	<.06	<.06	<.06	<.06	<.10	<.06	<.06	<.06
14	Ruthenium	<.13	<.19	<.19	<.19	<.19	<.19	<.19	<.19	<.19
15	Molybdenum	14.	1.9	18.	4.7	4.5	8.3	4.6	7.4	4.7
16	Strontium	42.	42.	42.	21.	10.	34.	10.	29.	9.1
17	Selenium	0.16	.07	.13	.01	.008	.01	.03	.01	.01
18	Arsenic	7.4	4.4	4.8	.48	1.1	1.4	2.2	3.0	2.7
19	Germanium	3.7	9.2	<2.7	2.1	12.	9.2	4.6	1.5	1.2
20	Gallium	.71	1.4	2.9	1.4	.99	2.7	1.4	1.8	.81
21	Zinc	20.	11.0	20.	20.	7.3	14.	10.	27.	14.
22	Copper	7.2	2.9	7.4	3.7	3.6	4.0	2.0	5.0	2.2
23	Nickel	2.3	4.2	7.3	<.53	1.4	<1.0	.60	<.74	<1.1
24	Cobalt	.21	.62	.48	.14	.31	.16	.60	.51	.06
25	Iron	.94%	2.7%	1.1 %	.71%	1.2 %	1.8 %	1.9 %	1.1 %	.14%
26	Manganese	95.	99.	150.	290.	140.	160.	50.	100.	57.
27	Chromium	3.5	3.7	15.	3.3	7.5	6.8	11.	8.8	2.4
28	Vanadium	17.	25.	30.	5.8	22.	25.	12.	17.	4.5
29	Titanium	50.	200.	220.	73.	140.	100.	220.	290.	51.
30	Calcium	3.2 %	1.1 %	1.2 %	.97%	.68%	1.1 %	1.0 %	1.3 %	.64%
31	Potassium	2.2 %	1.5 %	2.5 %	2.0 %	1.2 %	1.9 %	2.1 %	1.5	1.1 %
32	Chlorine									
33	Sulphur	.21 %	.12 %	.13 %	.20 %	.14 %	.16 %	.17 %	.16 %	.12 %
34	Phosphorous	.11 %	740.	.30%	3000.	.13%	2100.	360.	920.	1400.
35	Silicon	13.9 %	18.4 %	11.4 %	3.8 %	25. %	18. %	17. %	12. %	4.5 %
36	Aluminum	5200.	5200.	5900.	2900.	5800.	5700.	6300.	5500.	1100.
37	Magnesium	.47%	.38%	.28%	.23%	.25%	.36%	.58%	.39%	.16%
38	Sodium	290.	270.	570.	840.	430.	360.	390.	360.	500.
39	Fluorine	4.9	56.	59.	17.	150.	110.	47.	16.	<5.
40	Boron	20.	5.8	30.	6.4	29.	5.8	6.2	3.9	3.6
41	Beryllium	.025	.08	.11	0.2	.10	.08	.03	.06	.02
42	Lithium	39.	25.	88.	59.	43.	58.	58.	39.	59.

(a) Source and content of composited vegetation samples (vegetation sample numbers correspond to soil samples taken from the same locations as listed in table A-8. Trace elements and heavy metals in the corresponding soil samples are listed in table A-4).

Composite 1 — FORBS. A composite of sample 3 from a pine covered area and sample 15 from eroded coal beds.
2 — FORBS ON OR NEAR COAL OUTCROPS. A composite of 5 and 15.
3 — FRINGED SAGEBRUSH ON WESTERN SLOPES. A composite of 13 and 21.
4 — GRASSES FROM INTERNAL BASINS. A composite of 6 and 12.
5 — FRINGED SAGEBRUSH ON EASTERN SLOPES. Sample 17.
6 — FRINGED SAGEBRUSH ON PINE COVERED AREA. Sample 27 from east plant site.
7 — FRINGED SAGEBRUSH ON HILL TOPS. A composite of 30 and 32 from east plant site.
8 — FORB FROM INTERNAL BASIN. Sample 36 from south plant site.
9 — FRINGED SAGEBRUSH FROM HIGH GROUND. Sample 37 from south plant site.

(b) To facilitate comparisons of trace element and heavy metal concentrations in water, soil, and vegetation samples, the same number is used for each element in all tables.

2) **Predominant Vegetation Types**

Although the interpretation of data in the tables listed above is largely reserved to other report sections, a brief description of the major vegetation will be useful in establishing the biological character of the three areas potentially affected by proposed activities. Following the initial reconnaissance survey, the mine area was divided into the following six vegetative types or categories:

1. Rough breaks type, a heterogeneous category, containing a composite of range sites and upland vegetation types and corresponding to the Soil Conservation Service soil classification of the same name;
2. Heavy sagebrush type, composed primarily of a big sagebrush-grass mixture with big sagebrush canopy cover ranging from 15 to 25 percent;
3. Scattered sagebrush type, a uniform and evenly dispersed mixture of groups (2) and (3), with the ground cover of big sagebrush reduced to less than 10 percent;
4. Grasslands type, dominated by grasses with some forbs and few, if any, shrubs present;
5. Scattered greasewood type, a bottomland community composed primarily of salinity tolerant vegetation adjacent to Porcupine and Antelope creeks in T41N, R70W;
6. Creek bottom type, a bottomland community on better drained and less saline alluvial soils than category number 5. This type may include willow and plains cottonwood.

Abandoned cultivated fields (T42N, R70W) and introduced grass trials (T42N, R69W) within the mine lease area were recorded, but were of insignificant size or ecological value to be included and analyzed as separate categories.

The east plant site is characterized by sagebrush-grass communities over approximately 80 percent of the area with flat bottomland representing the remaining 20 percent. Because of the close proximity of most of the site to stock-watering windmills, it has been heavily grazed in the past. None of the vegetation types inventoried at the east plant site was classified as hayfields, although several introduced plant species were observed in the grassy bottomland (table A-17).

The proposed south plant site is located in an area composed mostly of upland hayfields bordered by native sagebrush-grass communities and old abandoned fields. These three categories were selected to be representative of the proposed site and its immediate surroundings. The eastern half of Section 34 and extensive acreage to the north and east have been seeded for hay production (upland hayfields) with small borders of sagebrush-grass vegetation retained between the fields. A limited acreage of abandoned cropland, uncultivated for the past 40 to 50 years is present in the adjoining township (Sec. 3, T34N, R70W).

A salient feature of all three areas is revealed by the fact that total perennial ground cover seldom exceeds 25 percent (tables A-16 through A-18). Therefore, 75 percent or more of the ground surface normally lacks vegetative cover. This reflects the fact that in arid regions each plant must tap a large volume of soil in order to obtain adequate water. Thus, only widely spaced perennial plants can be successful over the long term. Others may establish in the intervening spaces during moist periods but will lose the competition for soil moisture during dry periods to more extensively rooted plants.

d. Small Mammals

1) Methods

Because of their importance as prey species in terrestrial communities and their capacity to exert substantive damage on plant producers during population outbreaks, a major effort was made to inventory and obtain population parameters for small mammals. Population parameters were obtained from permanently staked grids consisting of 144 individual Sherman live traps spaced 50 feet apart in a 12 x 12 configuration. One such grid was established in the predominant vegetation type on the mine area and on the south and east plant sites. Traps, baited with rolled oats mixed in peanut butter, were set at dawn (to sample day-active mammals) and in the late afternoon (to sample night-active animals) over a 5 day period. On first capture each animal was marked with a unique combination of amputated toes and released.

Two methods of toe clipping were used. At the mine area, from the inside toes outward, toes of the left hind foot were numbered 1 to 5, the right hind foot 6 to 10, the left front foot 20 to 80 (4 toes) and the right front foot 100 to 400. This method proved unsatisfactory for species like the kangaroo rat (*Dipodomys ordii*) which have a variable number of toes. Consequently a different method, illustrated in figure A-6, was used on the two plant site grids.

All captures during a five day trap period were recorded as to study area, species, sex, reproductive condition, age class, identification number, and live weight to the nearest gram (taken with a hand-held spring scale).

The Rochelle mine grid was trapped in early June, 1973 to provide estimates of lower population levels, and in late August, to measure higher population levels. The two plant sites were trapped only during late September. Population density estimates incorporated corrections for differences in average trap range by the boundary strip method.[1] Basically, the procedure was to average the best trap range records in each animal category, calculate the radius of a circle of equal area and add a boundary strip of equal width to the grid perimeter. This has the effect of adjusting the

1 Broadbooks, 1970. Populations of the Yellow Pine Chipmunk, *Eutamias amoenus*. Amer. Midl. Natur. 83: 472-488.

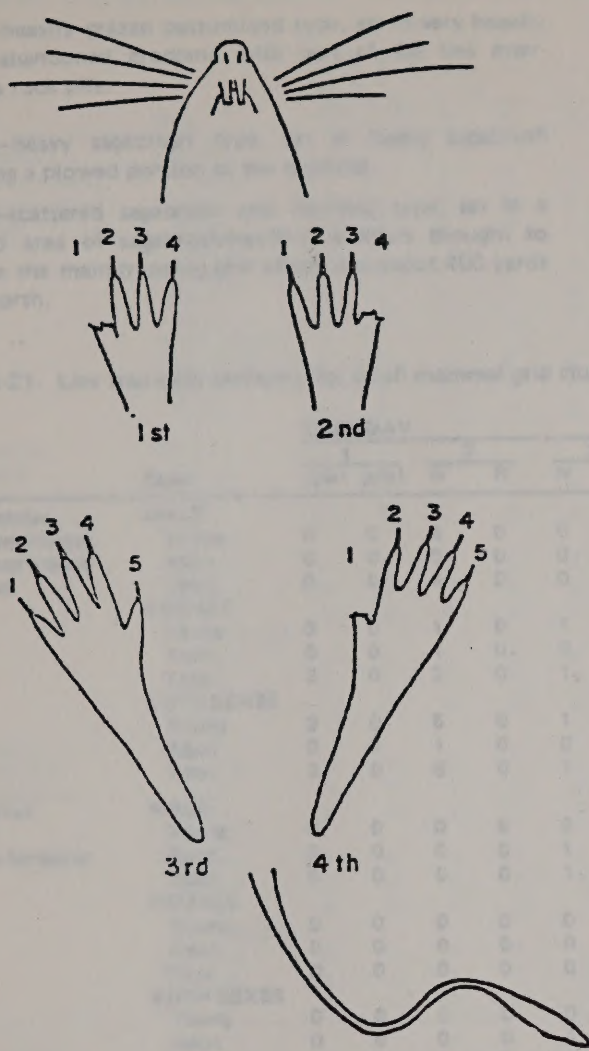

Figure A-6. Four digit numbers for rodent marking — showing rodent #1401.

estimated "trapped area" to allow for differences in home ranges among the various animal categories. If the animals in a given category are foraging widely, the effective area is enlarged and the estimated number of animals per unit area is correspondingly reduced.

A limitation of live-trapping only one grid is that it covers only about 7 acres and may not encompass all habitat types in a given sampling area. In order to obtain a more complete inventory and indices of relative abundance for small mammals over a range of habitats, one line transect of 20 museum special snap-traps, spaced approximately 30 feet apart, was established in the predominant vegetation type, and similar trap lines were established in all the other vegetation types. Lines in the predominant vegetation type were located far enough away to prevent interference with activity on the live-trapping grid.

2) Sampling Locations

All small mammal trapping locations are shown on figures A-3—A-5 and described as follows:

a Mine Area: Live trapping grid—scattered sagebrush type, in typical mixture of short grasses and scattered sagebrush with a heavy admixture of plains pricklypear cactus indicative of over-grazing.

Line 1—scattered sagebrush type, in the same type of vegetation as above on a bench one-quarter mile north of the live trapping grid.

Line 2—grassy bottomland type, along an intermittent stream bed with dense meadow grasses in the bottom and patches of heavy sage along the banks.

Line 3—grassland type, in an area which has been cleared of sagebrush and reseeded to grasses, mostly crested wheatgrass. Native species are re-invading the area extensively.

Line 4—heavy sagebrush type.

Line 5—rough breaks type, in a zone of scattered ponderosa pine with low ground cover.

Line 6—rough breaks type, on a steep north-facing shale and sandstone slope with outcrops of clinker material from the underlying coal beds.

b) East Plant Site: Live trapping grid—scattered sagebrush type, in typical mixture of sagebrush (denser than on the mine area) and grasses with a less dense admixture of pricklypear cactus on a moderately eroded, gently western slope.

Line 1—scattered sagebrush type, similar to the above, on the same slope and 200 yards south of the live-trapping grid.

Line 2—cottonwood bottomland type, in drainage below small reservoirs, along the bank under scattered cottonwoods.

Line 3—heavy sagebrush type, unusually heavy sagebrush zone at the base of small hills but above recent flood-water line.

Line 4—rough breaks type, along rather barren western slope under scattered ponderosa pine.

c) South Plant Site: Live trapping grid—scattered sagebrush and hayfield type, this alternative plant site as originally described to us consisted primarily of a large hayfield bordered by scattered sagebrush steppe vegetation; the grid was set half in the hayfield and half in the adjacent sagebrush vegetation.

Line 1—heavily grazed pastureland type, set in very heavily grazed abandoned cropland with part of the line intersecting a rock pile.

Line 2—heavy sagebrush type, set in heavy sagebrush bordering a plowed portion of the hayfield.

Line 3—scattered sagebrush and hayfield type, set in a localized area of sagebrush-hayfield mixture thought to resemble the main trapping grid which was about 400 yards to the north.

3) Results

Analysis of live-trapping records from the permanent grids, in categories separated according to trap period, study area, species, sex, and age class, yielded information on the number of animals captured (tables A-21 through A-24, the percentage of animals surviving into subsequent trap periods, as a measure of longevity (table A-25), population densities per unit of area (tables A-25 through A-29), the average distances traveled between consecutive captures (table A-30) and average weights (table A-31).

Table A-21. Live trap data summary for small mammal grid studies at the Rochelle mine area (June 20 - June 25, 1973)

		TRAP DAY											
		1		2		3		4		5		Total	
Species	Class	N[a]	R[b]	N	R	N	R	N	R	N	R	N	R
Spermophilus	MALE												
tridecemlineatus	Young	0	0	4	0	0	3	2	4	0	0	6	7
(13-lined ground	Adult	0	0	0	0	0	0	1	0	0	0	1	0
squirrel)	Total	0	0	4	0	0	3	3	4	0	0	7	7
	FEMALE												
	Young	3	0	1	0	1	2	1	3	0	0	6	5
	Adult	0	0	1	0	0	0	2	0	0	0	3	0
	Total	3	0	2	0	1	2	3	3	0	0	9	5
	BOTH SEXES												
	Young	3	0	5	0	1	5	3	7	0	0	12	12
	Adult	0	0	1	0	0	0	3	0	0	0	4	0
	Total	3	0	6	0	1	5	6	7	0	0	16	12
Dipodomys	MALE												
ordii	Young	0	0	0	0	0	0	0	0	0	0	0	0
(Ord's kangaroo	Adult	0	0	0	0	1	0	0	0	0	0	1	0
rat)	Total	0	0	0	0	1	0	0	0	0	0	1	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0	0
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	1	0	0	0	0	0	1	0
	Total	0	0	0	0	1	0	0	0	0	0	1	0
Peromyscus	MALE												
maniculatus	Young	1	0	1	0	2	0	1	0	1	0	6	0
(deer mouse)	Adult	2	0	0	2	1	2	0	2	1	0	4	6
	Total	3	0	1	2	3	2	1	2	2	0	10	6
	FEMALE												
	Young	2	0	0	0	1	0	1	1	0	1	4	2
	Adult	3	1	0	3	0	2	0	2	0	2	3	10
	Total	5	1	0	3	1	2	1	3	0	3	7	12
	BOTH SEXES												
	Young	3	0	1	0	3	0	2	1	1	1	10	2
	Adult	5	1	0	5	1	4	0	4	1	2	7	16
	Total	8	1	1	5	4	4	2	5	2	3	17	18
Lagurus	MALE												
curtatus	Young	0	0	0	0	0	0	0	0	0	0	0	0
(sagebrush	Adult	0	0	0	0	0	0	0	0	0	0	0	0
vole)	Total	0	0	0	0	0	0	0	0	0	0	0	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	1	0	0	0	0	0	0	0	1	0
	Total	0	0	1	0	0	0	0	0	0	0	1	0
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	1	0	0	0	0	0	0	0	1	0
	Total	0	0	1	0	0	0	0	0	0	0	1	0

(a) N — New
(b) R — Recaptured

Table A-22. Live trap data summary for small mammal grid studies at the Rochelle mine area (August 28 - August 31, 1973)

		TRAP DAY									
		1		2		3		4		Total	
Species	Class	N[a]	R[b]	N	R	N	R	N	R	N	R
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE										
	Young	0	0	2	0	1	0	0	0	3	0
	Adult	0	0	0	0	0	0	1	0	1	0
	Total	0	0	2	0	1	0	1	0	4	0
	FEMALE										
	Young	2	0	0	0	1	1	0	2	3	3
	Adult	1	0	0	1	0	1	0	0	1	2
	Total	3	0	0	1	1	2	0	2	4	5
	BOTH SEXES										
	Young	2	0	2	0	2	1	0	2	6	3
	Adult	1	0	0	1	0	1	1	0	2	2
	Total	3	0	2	1	2	2	1	2	8	5
Perognathus fasciatus (olive-backed pocket mouse)	MALE										
	Young	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0
	FEMALE										
	Young	1	0	0	0	0	0	0	1	1	1
	Adult	0	0	0	0	0	0	0	0	0	0
	Total	1	0	0	0	0	0	0	1	1	1
	BOTH SEXES										
	Young	1	0	0	0	0	0	0	1	1	1
	Adult	0	0	0	0	0	0	0	0	0	0
	Total	1	0	0	0	0	0	0	1	1	1
Peromyscus maniculatus (deer mouse)	MALE										
	Young	1	0	0	2	0	1	4	0	5	3
	Adult	2	1	1	2	2	1	1	3	6	7
	Total	3	1	1	4	2	2	5	3	11	10
	FEMALE										
	Young	2	0	1	1	1	3	0	2	4	6
	Adult	3	0	0	3	0	1	2	2	5	6
	Total	5	0	1	4	1	4	2	4	9	12
	BOTH SEXES										
	Young	3	0	1	3	1	4	4	2	9	9
	Adult	5	1	1	5	2	2	3	5	11	13
	Total	8	1	2	8	3	6	7	7	20	22

(a) N — New

(b) R — Recaptured

Table A-23. Live trap data summary for small mammal grid studies at the east plant site (September 28 - October 2, 1973)

Species	Class	TRAP DAY 1 N(a)	1 R(b)	2 N	2 R	3 N	3 R	4 N	4 R	5 N	5 R	Total N	Total R
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	1	0	0	1	0	1	0	0	0	0	1	2
	Total	1	0	0	1	0	1	0	0	0	0	1	2
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0	0
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	1	0	0	1	0	1	0	0	0	0	1	2
	Total	1	0	0	1	0	1	0	0	0	0	1	2
Perognathus fasciatus (olive-backed pocket mouse)	MALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	1	0	0	0	0	0	1	0
	Total	0	0	0	0	1	0	0	0	0	0	1	0
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	1	0	0	0	0	0	1	0
	Total	0	0	0	0	1	0	0	0	0	0	1	0
Dipodomys ordii (Ord's kangaroo rat)	MALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	10	0	3	5	0	4	3	4	1	2	17	15
	Total	10	0	3	5	0	4	3	4	1	2	17	15
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	10	0	3	5	0	4	3	4	1	2	17	15
	Total	10	0	3	5	0	4	3	4	1	2	17	15
Peromyscus maniculatus (deer mouse)	MALE												
	Young	1	0	0	1	0	1	1	1	1	1	3	4
	Adult	7	0	2	7	2	6	1	10	1	6	13	29
	Total	8	0	2	8	2	7	2	11	2	7	16	33
	FEMALE												
	Young	2	0	1	1	0	1	0	2	0	0	3	4
	Adult	3	0	0	3	2	2	0	3	2	3	7	11
	Total	5	0	1	4	2	3	0	5	2	3	10	15
	BOTH SEXES												
	Young	3	0	1	2	0	2	1	3	1	1	6	8
	Adult	10	0	2	10	4	8	1	13	3	9	20	40
	Total	13	0	3	12	4	10	2	16	4	10	26	48
Onychomys leucogaster (northern grass-hopper mouse)	MALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	1	0	2	0	3	0
	Total	0	0	0	0	0	0	1	0	2	0	3	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	1	0	0	0	0	0	1	0
	Total	0	0	0	0	1	0	0	0	0	0	1	0
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	1	0	1	0	2	0	4	0
	Total	0	0	0	0	1	0	1	0	2	0	4	0

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Species	Class	TRAP DAY 1 N[a]	1 R[b]	2 N	2 R	3 N	3 R	4 N	4 R	5 N	5 R	Total N	Total R
Lagurus curtatus (sagebrush vole)	MALE												
	Young	0	0	0	0	0	0	0	0	1	0	1	0
	Adult	0	0	0	0	1	0	0	0	0	0	1	0
	Total	0	0	0	0	1	0	0	0	1	0	2	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	0	0	1	0	1	0
	Total	0	0	0	0	0	0	0	0	1	0	1	0
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	1	0
	Adult	0	0	0	0	0	0	0	0	1	0	2	0
	Total	0	0	0	0	0	0	0	0	1	0	3	0

(a) N — New

(b) R — Recaptured

Table A-24. Live trap data summary for small mammal grid studies at the south plant site (September 28 - October 3, 1973)

Species	Class	TRAP DAY 1 N[a]	1 R[b]	2 N	2 R	3 N	3 R	4 N	4 R	5 N	5 R	Total N	Total R
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	1	0	0	0	0	1	0	0	1	1
	Total	0	0	1	0	0	0	0	1	0	0	1	1
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	2	0	0	0	0	4	0	2	0	0	2	6
	Total	2	0	0	0	0	4	0	2	0	0	2	6
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	2	0	1	0	0	4	0	3	0	0	3	7
	Total	2	0	1	0	0	4	0	3	0	0	3	7
Perognathus fasciatus (olive-backed pocket mouse)	MALE												
	Young	1	0	0	0	0	0	0	0	0	0	1	0
	Adult	0	0	0	0	0	0	0	0	0	0	0	0
	Total	1	0	0	0	0	0	0	0	0	0	1	0
	FEMALE												
	Young	1	0	1	0	0	1	0	0	0	1	2	2
	Adult	0	0	0	0	0	0	1	0	0	0	1	0
	Total	1	0	1	0	0	1	1	0	0	1	3	2
	BOTH SEXES												
	Young	2	0	1	0	0	1	0	0	0	1	3	2
	Adult	0	0	0	0	0	0	1	0	0	0	1	0
	Total	2	0	1	0	0	1	1	0	0	1	4	2
Dipodomys ordii (Ord's kangaroo rat)	MALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	0	0	0	0	0	0	0	0	0	0
	Total	0	0	0	0	0	0	0	0	0	0	0	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	1	0	1	1	0	3	1	1	3	5
	Total	0	0	1	0	1	1	0	3	1	1	3	5
	BOTH SEXES												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	1	0	1	1	0	3	1	1	3	5
	Total	0	0	1	0	1	1	0	3	1	1	3	5

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		TRAP DAY											
		1		2		3		4		5		Total	
Species	Class	N[(a)]	R[(b)]	N	R	N	R	N	R	N	R	N	R
Reithrodontomys	MALE												
megalotis	Young	0	0	0	0	0	0	3	0	1	0	4	0
(western harvest	Adult	0	0	0	0	0	0	0	0	0	0	0	0
mouse)	Total	0	0	0	0	0	0	3	0	1	0	4	0
	FEMALE												
	Young	0	0	0	0	0	0	0	0	0	0	0	0
	Adult	0	0	1	0	1	1	0	2	1	0	3	3
	Total	0	0	1	0	1	1	0	2	1	0	3	3
	BOTH SEXES												
	Young	0	0	0	0	0	0	3	0	1	0	4	0
	Adult	0	0	1	0	1	1	0	2	1	0	3	3
	Total	0	0	1	0	1	1	3	2	2	0	7	3
Peromyscus	MALE												
maniculatus	Young	2	0	6	2	4	7	2	5	1	4	15	18
(deer mouse)	Adult	5	2	0	5	0	3	1	2	1	3	7	15
	Total	7	2	6	7	4	10	3	7	2	7	22	33
	FEMALE												
	Young	0	0	3	0	4	1	1	2	5	2	13	5
	Adult	1	0	1	1	0	3	0	2	5	1	7	7
	Total	1	0	4	1	4	4	1	4	10	3	20	12
	BOTH SEXES												
	Young	2	0	9	2	8	8	3	7	6	6	28	23
	Adult	6	2	1	6	0	6	1	4	6	4	14	22
	Total	8	2	10	8	8	14	4	11	12	10	42	45
Onychomys	MALE												
leucogaster	Young	0	0	0	0	1	0	0	1	0	1	1	2
(northern grass-	Adult	0	0	0	0	0	0	0	0	0	0	0	0
hopper mouse)	Total	0	0	0	0	1	0	0	1	0	1	1	2
	FEMALE												
	Young	0	0	0	0	0	0	0	0	1	0	1	0
	Adult	0	0	1	0	1	1	0	1	0	2	2	4
	Total	0	0	1	0	1	1	0	1	1	2	3	4
	BOTH SEXES												
	Young	0	0	0	0	1	0	0	1	1	1	2	2
	Adult	0	0	1	0	1	1	0	1	0	2	2	4
	Total	0	0	1	0	2	1	0	2	1	3	4	6
Microtus	MALE												
pennsylvanicus	Young	0	0	0	0	0	0	0	0	0	0	0	0
(meadow vole)	Adult	0	0	0	0	0	0	0	0	1	0	1	0
	Total	0	0	0	0	0	0	0	0	1	0	1	0
	FEMALE												
	Young	0	0	0	0	0	0	1	1	1	1	2	2
	Adult	0	0	0	0	1	0	0	0	0	0	1	0
	Total	0	0	0	0	1	0	1	1	1	1	3	2
	BOTH SEXES												
	Young	0	0	0	0	0	0	1	1	1	1	2	2
	Adult	0	0	0	0	1	0	0	0	1	0	2	0
	Total	0	0	0	0	1	0	1	1	2	1	4	2

(a) N — New

(b) R — Recaptured

Table A-25. Survival of small mammals between trapping periods on the Rochelle mine live-trap grid (June 25 - August 28, 1973)

Species	Class	No. captures first trap period	No. survivors from first trap period captured in second trap period	Percent survival
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE			
	Young	6	1	16.7
	Adult	1	0	0
	Total	7	1	14.3
	FEMALE			
	Young	6	1	16.7
	Adult	3	0	0
	Total	9	1	11.1
	BOTH SEXES			
	Young	12	1	8.3
	Adult	4	0	0
	Total	16	1	6.2
Peromyscus maniculatus (deer mouse)	MALE			
	Young	6	1	16.7
	Adult	4	2	50.0
	Total	10	3	30.0
	FEMALE			
	Young	4	1	25.0
	Adult	3	1	33.3
	Total	7	2	28.6
	BOTH SEXES			
	Young	10	2	20.0
	Adult	7	3	42.8
	Total	17	5	29.4
All other species		2	0	0
Total		35	6	17.1

Table A-26. Estimated average home range and density of small mammals for the Rochelle mine live-trap grid in scattered sagebrush (June 20-25, 1973)

Species	Class	Average Trap range (acres)	Corrected grid area (acres)[a]	Individuals 10 acres[b]	No. individuals captured
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE				
	Young	.31	8.70	5.7	5
	Adult	–	–	–	1
	Total	.31	8.70	6.9	6
	FEMALE				
	Young	.34	8.79	8.0	7
	Adult	–	–	–	3
	Total	.34	8.79	11.4	10
	BOTH SEXES				
	Young	.32	8.74	13.7	12
	Adult	–	–	–	4
	Total	.32	8.74	18.3	16
Peromyscus maniculatus (deer mouse)	MALE[c]	3/			
	Young	–	–	–	6
	Adult	.81	9.88	4.0	4
	Total	.81	9.88	10.1	10
	FEMALE				
	Young	.44	9.04	4.4	4
	Adult	.73	9.38	3.2	3
	Total	.52	9.25	7.6	7
	BOTH SEXES				
	Young	.44	9.04	11.2	10
	Adult	.67	9.59	7.3	7
	Total	.66	9.56	17.8	17

(a) Actual grid area = 6.94 acres.

(b) Computed by boundary strip method.

(c) Insufficient recaptures to compute.

Table A-27. Estimated average home range and density of small mammals for the Rochelle mine live-trap grid in scattered sagebrush (August 28 - 31, 1973).

Species	Class	Average Trap range (acres)	Corrected grid area (acres)[a]	Individuals 10 acres[b]	No. individuals captured
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE				
	Young	–	–	–	0
	Adult	–	–	–	4
	Total	–	–	–	4
	FEMALE				
	Young	.22	8.43	4.7	4
	Adult	–	–	–	0
	Total	.22	8.43	4.7	–
	BOTH SEXES				
	Young	–	–	.47	0
	Adult	.22	8.43	–	8
	Total	.22	8.43	.47	8
Peromyscus maniculatus (deer mouse)	MALE				
	Young	(c)	–	–	5
	Adult	.30	8.68	6.9	6
	Total	.41	8.97	12.3	11
	FEMALE				
	Young	.52	9.27	4.3	4
	Adult	.28	8.62	5.8	5
	Total	.40	8.96	10.0	9
	BOTH SEXES				
	Young	.59	9.42	9.6	9
	Adult	.30	8.66	12.7	11
	Total	.41	8.97	22.3	20

(a) Actual grid area = 6.94 acres.

(b) Computed by boundary strip method.

(c) Insufficient recaptures to compute.

Table A-28. Estimated average home range and density of small mammals for the east plant site live-trap grid in scattered sagebrush (September 28 - October 2, 1973)

Species	Class	Average trap range (acres)	Corrected grid area (acres)[a]	Individuals 10 acres[b]	No. individuals captures
Dipodomys ordii (Ord's kangaroo rat)	MALE				
	Young	–	–	–	0
	Adult	–	–	–	0
	Total	–	–	–	0
	FEMALE				
	Young	–	–	–	0
	Adult	.40	8.94	19.0	17
	Total	.40	8.94	19.0	17
	BOTH SEXES				
	Young	–	–	–	–
	Adult	.40	8.94	19.0	17
	Total	.40	8.94	19.0	17
Peromyscus maniculatus (deer mouse)	MALE	(c)			
	Young	–	–	–	3
	Adult	.51	9.24	14.1	13
	Total	.53	9.28	17.2	16
	FEMALE				
	Young	–	–	–	3
	Adult	.52	9.25	7.6	7
	Total	.55	9.32	10.7	10
	BOTH SEXES				
	Young	.61	9.46	6.3	6
	Adult	.51	9.24	21.6	20
	Total	.54	9.29	28.0	26

(a) Actual grid area = 6.94 acres.

(b) Computed by boundary strip method.

(c) Insufficient recaptures to compute.

Table A-29. Estimated average home range and density of small mammals for the south plant site live-trap grid in scattered sagebrush and hayfield (September 28 - October 2, 1973)

Species	Class	Average trap range (acres)	Corrected grid area (acres)[a]	Individuals 10 acres[b]	No. individuals captured
Peromyscus maniculatus (deer mouse)	MALE				
	Young	.32	8.73	18.3	16
	Adult	.47	9.13	6.6	6
	Total	.40	8.94	24.6	22
	FEMALE				
	Young	.15	8.14	14.7	12
	Adult	.16	8.18	8.6	7
	Total	.15	8.16	23.3	19
	BOTH SEXES				
	Young	.24	8.46	33.1	28
	Adult	.32	8.71	14.9	13
	Total	.16	8.59	49.0	41

(a) Actual grid area = 6.94 acres.

(b) Computed by boundary strip method.

Table A-30. Average distance, in feet, traveled by small mammal species between consecutive captures on live-trap grids at the mine area and the south and east plant sites within specified time periods (1973)

SITE		MALE			FEMALE			BOTH SEXES		
Inclusive Dates	Species	(n)[a]	$\overline{x}$[b]	Confidence Limits[c]	(n)	$\overline{x}$	Confidence Limits	(n)	$\overline{x}$	Confidence Limits
Mine area 6/20/73 – 6/25/73	*Spermophilus tridecemlineatus* (13-lined ground squirrel)	6	114.3	13.3-215.3	5	160.7	87.7-233.7	11	135.3	80.3-190.3
	Peromyscus maniculatus (deer mouse)	6	244.0	110.7-377.3	12	174.7	109.4-240.0	18	197.7	141.4-254.0
Mine area 8/28/73 - 8/31/73	*Spermophilus tridecemlineatus* (13-lined ground squirrel)	0	–	–	5	120.7	56.0-185.4	5	120.7	56.0-185.4
	Perognathus fasciatus (olive-backed pocket mouse)	0	–	–	1	160.0	–	1	160.0	–
	Peromyscus maniculatus (deer mouse)	9	166.7	116.0-217.4	11	164.3	122.6-206.0	20	165.3	136.0-194.5
East plant site 9/28/73 – 10/2/73	*Dipodomys ordii* (ord's kangaroo rat)	0	–	–	14	142.7	60.0-225.4	14	142.7	60.0-225.4
	Peromyscus maniculatus (deer mouse)	26	141.0	113 7-168.3	15	122.0	88.3-155.7	41	134.0	109.7-158.3
South plant site 9/28/73 – 10/2/73	*Spermophilus tridecemlineatus* (13-lined ground squirrel)	1	353.3	–	3	216.7	61.7-371.7	4	250.7	115.0-386.4
	Perognathus fasciatus (olive-backed pocket mouse)	0	–	–	1	183.3	–	1	183.3	–
	Dipodomys ordii (Ord's kangaroo rat)	0	–	–	3	115.7	0-251.7	3	115.7	0-251.7
	Reithrodontymys megalotus (western harvest mouse)	0	–	–	3	66.7	0-138.4	3	–	0-138.4
	Peromyscus maniculatus (deer mouse)	25	115.0	87.3-142.7	7	84.8	53.4-116.2	32	107.3	85.0-129.6
	Onychomys leucogaster (northern grass-hopper mouse)	2	92.3	0-359.0	2	80.0	0-461.3	4	80.7	24.4-137.0

(a) (n) = number of individuals in sample

(b) $\overline{x}$ = sample mean

(c) 95% confidence limits — by chance alone, the real average distance traveled between consecutive captures could fall outside the indicated ranges in only 5 out of 100 trials.

Table A-31. Average weight, in grams, for adult small mammals captured on live-trap grids at the mine area and the south and east plant sites within specified time periods (1973)

SITE Inclusive Dates	Species	MALE (n)(a)	MALE $\overline{x}$(b)	MALE Confidence Limits(c)	FEMALE (n)	FEMALE $\overline{x}$	FEMALE Confidence Limits	BOTH SEXES (n)	BOTH SEXES $\overline{x}$	BOTH SEXES Confidence Limits
Mine area 6/20/73 – 6/25/73	*Spermophilus tridecemlineatus* (13-lined ground squirrel)	1	98.0	–	3	94.3	771.-111.5	2	95.2	85.3-105.1
	Peromyscus maniculatus (deer mouse)	4	23.4	15.9-30.9	3	22.0	18.6- 25.4	7	22.8	20.2- 25.4
	Dipodomys ordii (Ord's kangaroo rat)	1	58.0	–	0	–	–	1	58.0	–
	Lagurus curtatus (sagebrush vole)	0	–	–	1	22.0	–	1	22.0	–
Mine area 8/28/73 – 8/31/73	*Spermophilus tridecemlineatus* (13-lined ground squirrel)	4	78.5	70.4-86.6	4	72.8	65.8- 79.8	8	75.6	71.0- 80.2
	Peromyscus maniculatus (deer mouse)	6	18.3	14.9-21.7	6	19.8	17.0- 22.6	12	19.1	17.2- 21.0
East plant site 9/28/73 10/2/73	*Spermophilus tridecemlineatus* (13-lined ground squirrel)	1	78.3	–	0	–	–	1	78.3	–
	Perognathus fasciatus (olive-backed pocket mouse)	0	–	–	1	10.0	–	1	10.0	–
	Dipodomys ordii (Ord's kangaroo rat)	0	–	–	14	62.4	58.8- 66.0	14	62.4	58.8- 66.0
	Peromyscus maniculatus (deer mouse)	13	19.4	17.9-20.9	7	15.4	12.7- 18.1	20	18.0	16.5- 19.5
	Onychomus leucogaster (northern grass-hopper mouse)	3	33.7	20.5-46.9	1	25.2	–	4	31.5	40.9- 22.1
	Lagurus curtatus (sagebrush vole)	1	26.0	–	1	17.0	–	2	21.5	0- 61.9
South plant site 9/28/73 – 10/2/73	*Spermophilus tridecemlineatus* (13-lined ground squirrel)	1	100.5	–	2	108.6	69.6-147.6	3	105.9	118.9- 92.
	Dipodomys ordii (Ord's kangaroo rat)	0	–	–	3	67.4	53.5- 81.3	3	67.4	53.5- 81.
	Reithrodontomys megalotis (western harvest mouse)	0	–	–	2	20.8	9.6- 32.0	2	20.8	9.6- 32.
	Onychomus leucogaster (northern grass-hopper mouse)	0	–	–	1	35.5	–	1	35.5	–
	Microtus pennsylvanicus (meadow vole)	1	37.0	–	1	46.0	–	2	41.5	1.1- 81.
	Peromyscus maniculatus (deer mouse)	6	20.1	19.1-21.1	6	27.4	23.6- 31.2	12	23.8	21.0- 26.

(a) (n) = number individuals captured (b) $\overline{x}$ = mean weight of individuals captured in grams
(c) 95% confidence limits – by chance alone, the real average population weights could fall outside the indicated ranges in only 5 out of 100 trials.

Analysis of snap-trapping records from line transects provide information on species diversity and relative abundance in five different vegetation types on the mine area in late spring (tables A-32 through A-36), in six vegetation types on the same area in late summer (tables A-37 through A-42), in four vegetation types on the east plant site in fall (tables A-43 through A-46) and in three vegetation types on the south plant site in fall (A-47 through A-49).

Table A-32. Summary of snap-trap data from Rochelle mine area, line 1 in scattered sagebrush (August 28-31, 1973)

Species	Class	TRAP DAY 1	2	3	Total
Spermophilus *tridecemlineatus* (13-lined ground squirrel)	MALE				
	Young	0	0	0	0
	Adult	0	0	0	0
	Total	0	0	0	0
	FEMALE				
	Young	0	0	0	0
	Adult	0	1	1	2
	Total	0	1	1	2
	BOTH SEXES				
	Young	0	0	0	0
	Adult	0	1	1	2
	Total	0	1	1	2
Peromyscus *maniculatus* (deer mouse)	MALE				
	Young	0	0	0	0
	Adult	1	2	1	4
	Total	1	2	1	4
	FEMALE				
	Young	2	0	2	4
	Adult	1	3	3	7
	Total	3	3	5	11
	BOTH SEXES				
	Young	2	0	2	4
	Adult	2	5	4	11
	Total	4	5	6	15

Table A-33. Summary of snap-trap data from Rochelle mine area, line 2 in grassy bottomland (June 21-25, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus *maniculatus* (deer mouse)	MALE					
	Young	0	1	0	0	1
	Adult	2	0	1	0	3
	Total	2	1	1	0	4
	FEMALE					
	Young	0	0	0	0	0
	Adult	1	0	0	0	1
	Total	1	0	0	0	1
	BOTH SEXES					
	Young	0	1	0	0	1
	Adult	3	0	1	0	4
	Total	3	1	1	0	5
Lagurus curtatus (sagebrush vole)	MALE					
	Young	0	2	0	0	2
	Adult	0	0	0	0	0
	Total	0	2	0	0	2
	FEMALE					
	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	BOTH SEXES					
	Young	0	2	0	0	2
	Adult	0	0	0	0	0
	Total	0	2	0	0	2

Table A-34. Summary of snap-trap data from Rochelle mine area, line 2 in grassy bottomland (August 28-31, 1973)

Species	Class	TRAP DAY 1	2	3	Total
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE				
	Young	0		0	0
	Adult	0		1	1
	Total	0		1	1
	FEMALE				
	Young	0		0	0
	Adult	0		0	0
	Total	0		0	0
	BOTH SEXES				
	Young	0		0	0
	Adult	0		1	1
	Total	0		1	1
Peromyscus *maniculatus* (deer mouse)	MALE				
	Young	1	0	0	1
	Adult	2	1	1	4
	Total	3	1	1	5
	FEMALE				
	Young	0	0	0	0
	Adult	1	0	2	3
	Total	1	0	2	3
	BOTH SEXES				
	Young	1	0	0	1
	Adult	3	1	3	7
	Total	4	1	3	8

Table A-35. Summary of snap-trap data from Rochelle mine area, line 3 in grassland (June 21-25, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus maniculatus (deer mouse)	MALE					
	Young	1	1	0	0	2
	Adult	1	0	0	0	1
	Total	2	1	0	0	3
	FEMALE					
	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	BOTH SEXES					
	Young	1	1	0	0	2
	Adult	1	0	0	0	1
	Total	2	1	0	0	3

Table A-36. Summary of snap-trap data from Rochelle mine area, line 3 in grassland (August 28-31, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus maniculatus (deer mouse)	MALE					
	Young	0	1	0	0	1
	Adult	0	0	0	3	3
	Total	0	1	0	3	4
	FEMALE					
	Young	0	0	0	0	0
	Adult	1	1	0	1	3
	Total	1	1	0	1	3
	BOTH SEXES					
	Young	0	1	0	0	1
	Adult	1	1	0	4	6
	Total	1	2	0	4	7

Table A-37. Summary of snap-trap data from Rochelle mine area, line 4 in heavy sagebrush (June 21-25, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE					
	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	FEMALE					
	Young	0	0	0	1	1
	Adult	0	0	0	0	0
	Total	0	0	0	1	1
	BOTH SEXES					
	Young	1	0	1	1	3
	Adult	0	0	0	0	0
	Total	1	0	1	1	3
Peromyscus maniculatus (deer mouse)	MALE					
	Young	1	1	0	0	2
	Adult	1	0	0	0	1
	Total	2	1	0	0	3
	FEMALE					
	Young	1	0	0	0	1
	Adult	0	1	0	1	2
	Total	1	1	0	1	3
	BOTH SEXES					
	Young	2	1	0	0	3
	Adult	1	1	0	1	3
	Total	3	2	0	1	6

Table A-38. Summary of snap-trap data from Rochelle mine area, line 4 in heavy sagebrush (August 28-31, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus maniculatus (deer mouse)	MALE					
	Young	0	0	0	0	0
	Adult	1	0	1	0	2
	Total	1	0	1	0	2
	FEMALE					
	Young	1	2	0	0	3
	Adult	0	0	0	0	0
	Total	1	2	0	0	3
	BOTH SEXES					
	Young	1	2	0	0	3
	Adult	1	0	1	0	2
	Total	2	2	1	0	5

Table A-39. Summary of snap-trap data from Rochelle mine area, line 5 in rough breaks and scattered pines (June 21-25, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus maniculatus (deer mouse)	MALE					
	Young	1	1	1	0	3
	Adult	1	4	0	2	7
	Total	2	5	1	2	10
	FEMALE					
	Young	2	0	0	0	2
	Adult	0	0	0	0	0
	Total	2	0	0	0	2
	BOTH SEXES					
	Young	3	1	1	0	5
	Adult	1	4	0	2	7
	Total	4	5	1	2	12

Table A-40. Summary of snap-trap data from Rochelle mine area, line 5 in rough breaks and scattered pines (August 28-31, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus maniculatus (deer mouse)	MALE					
	Young	2	0	0	0	2
	Adult	1	3	0	3	7
	Total	3	3	0	3	9
	FEMALE					
	Young	0	0	0	1	1
	Adult	1	1	2	1	5
	Total	1	1	2	2	6
	BOTH SEXES					
	Young	2	0	0	1	3
	Adult	2	4	2	4	12
	Total	4	4	2	5	15

Table A-41. Summary of snap-trap data from Rochelle mine area, line 6 in rough breaks and rock outcrops (June 21-25, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus	MALE					
maniculatus	Young	1	0	1	1	3
(deer mouse)	Adult	2	2	0	0	4
	Total	3	2	1	1	7
	FEMALE					
	Young	2	3	2	2	9
	Adult	4	4	1	0	9
	Total	6	7	3	2	18
	BOTH SEXES					
	Young	3	3	3	3	12
	Adult	6	6	1	0	13
	Total	9	9	4	3	25

Table A-42. Summary of snap-trap data from Rochelle mine area, line 6 in rough breaks and rock outcrops (August 28-31, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus	MALE					
maniculatus	Young	0	2	0	0	2
(deer mouse)	Adult	5	2	0	1	8
	Total	5	4	0	1	10
	FEMALE					
	Young	0	0	0	1	1
	Adult	1	1	1	0	3
	Total	1	1	1	1	4
	BOTH SEXES					
	Young	0	2	0	1	3
	Adult	6	3	1	1	11
	Total	6	5	1	2	14

Table A-43. Summary of snap-trap data from East plant site, line 1 in scattered sagebrush (September 29-October 2, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Dipodomys ordii	MALE					
(Ord's kangaroo	Young	0	0	0	0	0
rat)	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	FEMALE					
	Young	0	0	0	0	0
	Adult	1	1	0	0	2
	Total	1	1	0	0	2
	BOTH SEXES					
	Young	0	0	0	0	0
	Adult	1	1	0	0	2
	Total	1	1	0	0	2
Peromyscus	MALE					
maniculatus	Young	0	0	0	1	1
(deer mouse)	Adult	2	1	2	2	7
	Total	2	1	2	3	8
	FEMALE					
	Young	1	0	0	0	1
	Adult	0	0	0	1	1
	Total	1	0	0	1	2
	BOTH SEXES					
	Young	1	0	0	1	2
	Adult	2	1	2	3	8
	Total	3	1	2	4	10

Table A-44. Summary of snap-trap data from east plant site, line 2 in cottonwood bottomland (September 29-October 2, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus	MALE					
maniculatus	Young	1	0	1	1	3
(deer mouse)	Adult	3	4	2	5	14
	Total	4	4	3	6	17
	FEMALE					
	Young	2	0	1	0	3
	Adult	2	2	2	2	8
	Total	4	2	3	2	11
	BOTH SEXES					
	Young	3	0	2	1	6
	Adult	5	6	4	7	22
	Total	8	6	6	8	28

Table A-45. Summary of snap-trap data from east plant site line 3 in heavy sagebrush (September 29-October 2, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus	MALE					
maniculatus	Young	0	0	0	0	0
(deer mouse)	Adult	3	2	3	2	10
	Total	3	2	3	2	10
	FEMALE					
	Young	2	2	2	0	6
	Adult	1	2	1	3	7
	Total	3	4	3	3	13
	BOTH SEXES					
	Young	2	2	2	0	6
	Adult	4	4	4	5	17
	Total	6	6	6	5	23
Lagurus curtatus	MALE					
(sagebrush vole)	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	FEMALE					
	Young	0	0	0	0	0
	Adult	0	0	0	1	1
	Total	0	0	0	1	1
	BOTH SEXES					
	Young	0	0	0	0	0
	Adult	0	0	0	1	1
	Total	0	0	0	1	1

Table A-46. Summary of snap-trap data from east plant site, line 4 in rough breaks and scattered pines (September 29-October 2, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus	MALE					
maniculatus	Young	1	0	2	0	3
(deer mouse)	Adult	1	2	2	3	8
	Total	2	2	4	3	11
	FEMALE					
	Young	2	0	0	3	5
	Adult	4	3	1	2	10
	Total	6	3	1	5	15
	BOTH SEXES					
	Young	3	0	2	3	8
	Adult	5	5	3	5	18
	Total	8	5	5	8	26

Table A-47. Summary of snap-trap data from south plant site, line 1 in heavily grazed pasture land (September 28-October 2, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE					
	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	FEMALE					
	Young	1	0	0	0	1
	Adult	0	0	0	0	0
	Total	1	0	0	0	1
	BOTH SEXES					
	Young	1	0	0	0	1
	Adult	0	0	0	0	0
	Total	1	0	0	0	1
Peromyscus maniculatus (deer mouse)	MALE					
	Young	0	0	0	0	0
	Adult	1	0	0	0	1
	Total	1	0	0	0	1
	FEMALE					
	Young	0	0	0	0	0
	Adult	1	0	0	0	1
	Total	1	0	0	0	1
	BOTH SEXES					
	Young	0	0	0	0	0
	Adult	2	0	0	0	2
	Total	2	0	0	0	2

Table A-48. Summary of snap-trap data from south plant site, line 2 in heavy sagebrush (September 28-October 2, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Spermophilus tridecemlineatus (13-lined ground squirrel)	MALE					
	Young	0	0	0	0	0
	Adult	0	0	1	0	1
	Total	0	0	1	0	1
	FEMALE					
	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	BOTH SEXES					
	Young	0	0	0	0	0
	Adult	0	0	1	0	1
	Total	0	0	1	0	1
Perognathus fasciatus (olive-backed pocket mouse)	MALE					
	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	FEMALE					
	Young	1	1	0	0	2
	Adult	0	0	0	0	0
	Total	1	1	0	0	2
	BOTH SEXES					
	Young	1	1	0	0	2
	Adult	0	0	0	0	0
	Total	1	1	0	0	2
Peromyscus maniculatus (deer mouse)	MALE					
	Young	1	1	2	1	5
	Adult	3	1	1	0	5
	Total	4	2	3	1	10
	FEMALE					
	Young	1	2	0	1	4
	Adult	3	2	0	1	6
	Total	4	4	0	2	10
	BOTH SEXES					
	Young	2	3	2	2	9
	Adult	6	3	1	1	11
	Total	8	6	3	3	20
Onychomys leucogaster (northern grass-hopper mouse)	MALE					
	Young	0	0	0	0	0
	Adult	0	0	0	0	0
	Total	0	0	0	0	0
	FEMALE					
	Young	0	0	0	0	0
	Adult	0	0	0	1	1
	Total	0	0	0	1	1
	BOTH SEXES					
	Young	0	0	0	0	0
	Adult	0	0	0	1	1
	Total	0	0	0	1	1

Table A-49. Summary of snap-trap data at south plant site, line 3 in scattered sagebrush and hayfield (September 28-October 2, 1973)

Species	Class	TRAP DAY 1	2	3	4	Total
Peromyscus	MALE					
maniculatus	Young	1	0	1	0	2
(deer mouse)	Adult	2	0	1	0	3
	Total	3	0	2	0	5
	FEMALE					
	Young	1	2	1	0	4
	Adult	0	2	0	0	2
	Total	1	4	1	0	6
	BOTH SEXES					
	Young	2	2	2	0	6
	Adult	2	2	1	0	5
	Total	4	4	3	0	11

e. Rabbits and Hares

1) Methods

Rabbit and hare populations were censused at the mine area and each plant site along road-site transects beginning one hour after sundown on three consecutive nights during each sampling period. These standard routes, passing through all local vegetation types in approximately their extant proportions, covered distances of 10 miles at the mine area and 5 miles at each plant site. The vehicle was driven at 10 mph while an observer recorded odometer readings to the nearest one-tenth mile for rabbits observed within an estimated 75 feet to one side of the vehicle.

Observer accuracy in estimating the 75 foot cut-off boundary was checked by direct measurement at the beginning of each mile. Variation in these estimates was used to calculate the mean and 95 percent confidence limits for the estimated area sampled. Multiplying the length of a transect by the average estimated width and dividing the result into the total observed individuals of each species produced an estimate of rabbit numbers per unit of area.

2) Results

Estimated numbers of rabbits and hares for all sampling periods are presented in table A-50.

f. Big Game

1) Methods

The Thunder Basin portion of the Cheyenne River drainage supports a few elk (transplanted from Yellowstone Park), small herds of deer and numerous antelope. Most of the resident deer confine their activities to the rocky breaks and pine-covered hills surrounding the study areas. Antelope were consistently observed at all study areas, but because of the unpredictability on antelope movement and browse use from year to year, a one-year field study of antelope was not attempted. Data gathered over a period of years by the Wyoming Game and Fish Commission are summarized over large management units and are not easily applied to localized areas like the Rochelle mine. Nonetheless, these records and interviews with local Game and Fish personnel are regarded as the best information available concerning the importance of potentially affected areas to local antelope herds (personal interviews and Wyoming Game and Fish Commission report).[1]

According to Roger Wilson, big game biologist with the Wyoming Game and Fish Commission in Sheridan (personal communication), flight census flown over the Clarkelen management area extending south from Wright to Antelope Creek and east from highway 59 to the Rochelle Hills, an area enclosing the proposed mine area, revealed no summer antelope concentrations on the mine area. However, data from winter flights consistently showed antelope concentrations in that area. It may be that drifting of antelope away from winter storms (toward the southeast) tends to concentrate them in the area bounded on the east by pine-covered hills and on the south by the Antelope Creek and Porcupine Creek breaks. Thus, the mine area may be an important antelope winter range.

1 Wyoming Game and Fish Commission, 1970. Wyoming fish and wildlife plan, current status and inventory, big game—upland game for District 3. Game Division, Planning Report No. 36.

Table A-50. Estimated density of rabbits and hares (jackrabbits) at the mine area and south and east plant sites in specified months (1973).

Area	Night	Length of transect (miles)	Average width of transect (feet)	Estimated individuals/square mile: Cottontails	Estimated individuals/square mile: Jackrabbits
Mine area	1	10	76.4	55	48
(June)	2	10	73.1	51	65
	3	10	75.1	92	70
Average			74.9	66	61
95% confidence limits			70.7-79.1	10-122	33-89
Mine area	1	10	72.3	131	240
(August)	2	10	75.0	352	91
	3	10	79.1	280	99
Average			75.5	254	144
95% confidence limits			67.1-83.9	142-534	0-352
East plant site	1	5	75.0	98	140
(September)	2	5	77.6	13	27
	3	5	77.5	13	108
Average			76.7	41	92
95% confidence limits			73.0-80.4	0-163	0-237
South plant site	1	5	77.0	96	13
(September)	2	5	75.4	69	97
	3	5	76.0	27	69
Average			76.2	64	60
95% confidence limits			74.1-78.3	0-211	0-167

2) Results

Figures A-7 through A-10 show areas of winter antelope concentrations as revealed by four Wyoming Game and Fish Commission flight censuses flown during 1956 to 1962. Table A-51 shows a trend in antelope harvests throughout District 3 for 1960 through 1969. It may be assumed that the same general downward trends hold for the study areas. (Rochelle mine and east plant site) included in the district. Harvest data from the Clarkelen area for 1968 through 1972 are summarized in table A-52, showing a sharp increase in hunting pressure and a slight decrease in hunting success during recent years.

3) Endangered Mammals

The Wyoming Game and Fish Commission lists only one species, the black-footed ferret (*Mustela nigripes*), as being "endangered"; that is, whose prospect of survival and reproduction is in immediate jeopardy. According to Fortenbery,[1] the species has probably never been abundant and its existence has been closely tied to populations of prairie dogs which serve as its major food supply. A large prairie dog colony was periodically observed by ECI personnel at the east plant site, but neither actual ferrets nor their signs (trenches, scats or tracks) were observed. Mr. Donald Miller, Regional Information Specialist of the Wyoming Game and Fish Commission in Sheridan, (personal communication) reports a paucity of information relative to ferret populations in the area.

g. Other Native Mammals

Other native mammals possibly residing in study areas but not readily sampled due to low numbers or secretive habits are listed in table A-53 according to the nature of the evidence that they may be present (ranging from observations of the species by ECI personnel in the field to inference from published distribution maps).

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1 Fortenbery, D. K. 1972. Characteristics of the black-footed ferret. Bureau of Sport Fisheries and Wildlife, U. S. Dept. of Interior. Res. Public. 109. p. 8.

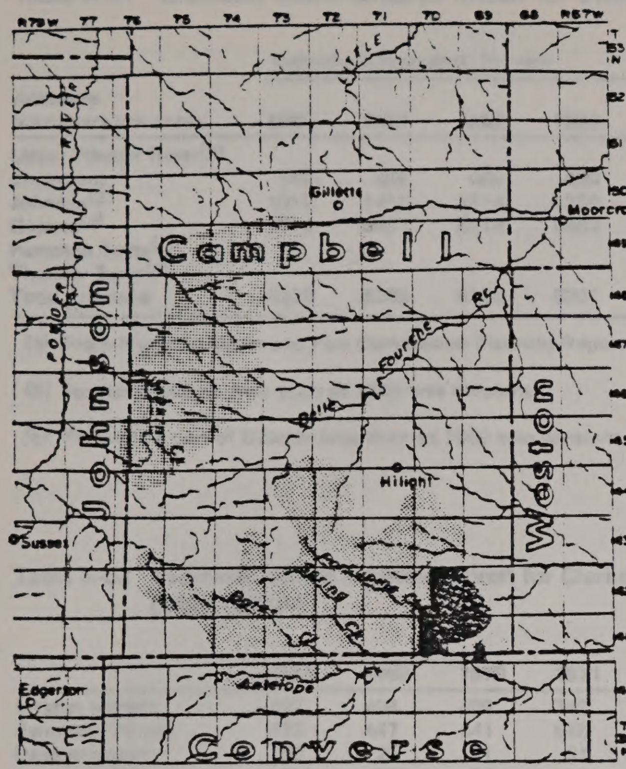

Figure A-7 Winter antelope concentration areas (shaded) for the southern portion of the Gillette Antelope Management Area (1955-1956)

-N-

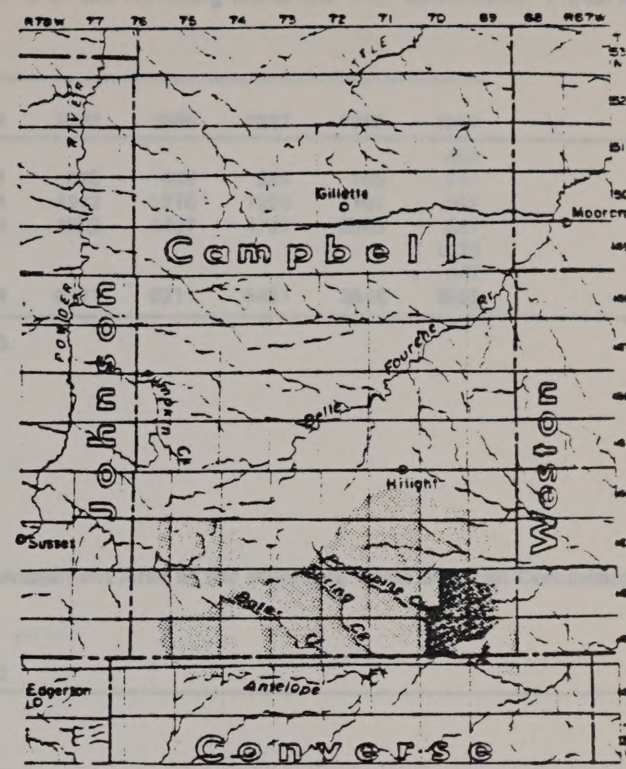

Figure A-9 Winter antelope concentration areas (shaded) for the southern portion of the Gillette Antelope Management Area (April, 1959)

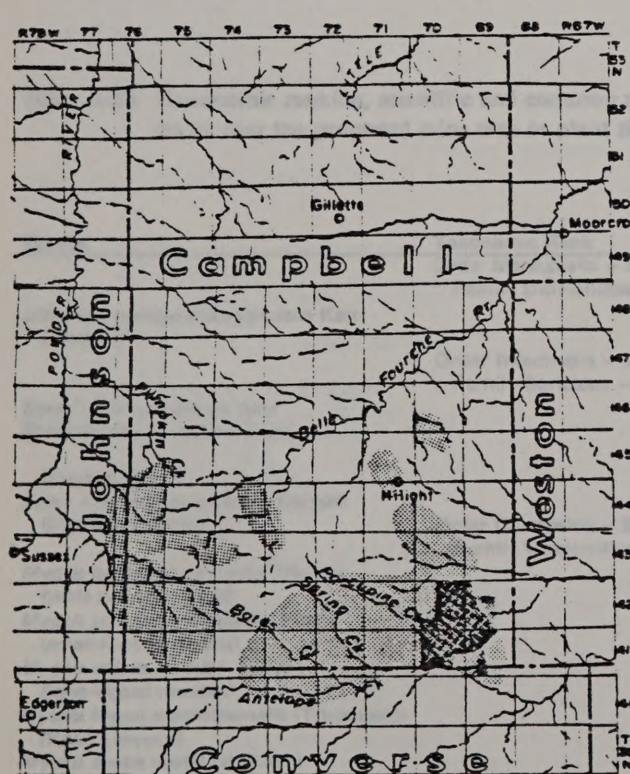

Figure A-8 Winter antelope concentration areas (shaded) for the southern portion of the Gillette Antelope Management Area (January, 1959)

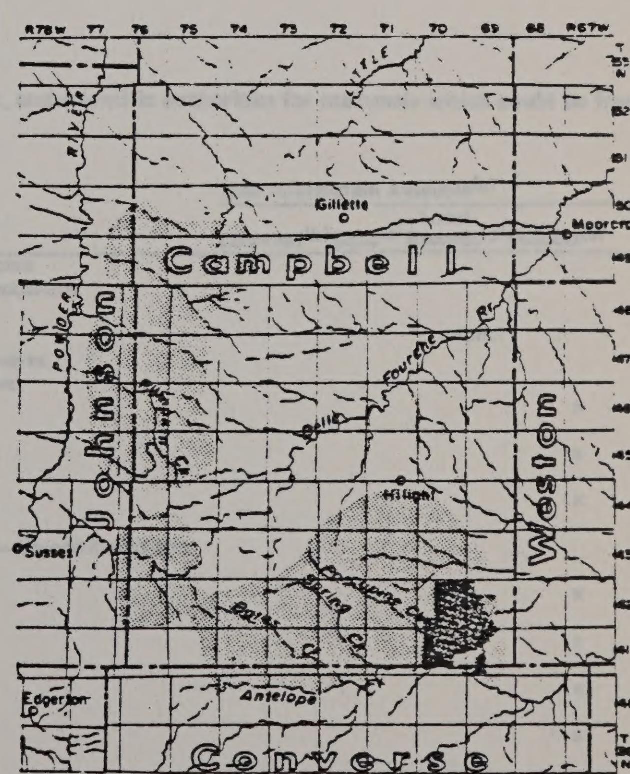

Figure A-10 Winter antelope concentration areas (shaded) for the southern portion of the Gillette Antelope Management Area (1961-1962)

Table A-51 Estimated annual antelope harvest for District No. 3 of the Wyoming Game and Fish Commission (1960-1969)(

Antelope management areas	Individuals harvested, by year 1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Upper Powder River[b]										456
Clearmont	415	458	468	460	467	520	446	389	186	137
Johnson[b]	1018	1416	1514	1278	1328	1342	1278	1295	1197	699
Gillette[c]	4773	6461	6214	4463	4724	4559	4487	4797	2563	547
Pumpkin Butte[c]										1576
Thunder Basin[c]										447
Total Antelope	6206	8335	8196	6201	6519	6421	6211	6481	3946	3862

(a) From Wyoming Game and Fish Commission Planning Report No. 36.

(b) Formerly Kaycee Area prior to 1969 area revisions.

(c) Formerly a part of Gillette Area prior to 1969 area revisions.

Table A-52 Estimated annual antelope harvest for Clarkelen Management Area of the Wyoming Game and Fish Commission (1968-1972)[a]

	1968	1969	1970	1971	1972
License holders	497	494	498	748	754
Estimated harvest	473	447	441	646	661
Days in season	20	20	21	31	23
Buck harvest	79%	78%	87%	82%	88%
Hunter success	95%	96%	97%	93%	92%
Average hunter days	2.76	2.13	2.28	2.29	2.54

(a) See text for a description of Clarkelen Management Area.

Table A-53 Taxonomic ranking, scientific and common names, and scientific authorities for mammals which could be found on or near the proposed mine area or plant sites

Species	Taxonomic Rank	Best Information Available[a] Observed[b]	Signs[c]	Local Records[d]	Possible[e]
	Order Marsupialia — Marsupials Family Didelphidae — Oppossums				
Didelphis marsupialis virginiana Kerr (opossum)				x(one)	
	Order Insectivora — Insectivores Family Soricidae — Shrews				
Sorex cinereus cinereu Kerr					x
Sorex cinereus haydeni Baird (masked shrew)					x
Sorex merriami leucogenys Osgood (Merriam's shrew)					x
	Order Chiroptera — Bats Family Vespertilionidae — Vespertilionid bats				
Myotis lucifugus carissima Thomas (little brown myotis)					x
Myotis subulatus subulatus (Say) (small-footed myotis)					x
Myotis volans interior Miller (long-legged myostis)					x
Myotis keenii septentrionalis (Trouessart) (Keen's myotis)					x
Myotis evotis evotis (H. Allen) (long-eared myotis)					x

(continued next page)

Species	Taxonomic Rank	Best Information Available[a] Observed[b]	Signs[c]	Local Records[d]	Possible[e]
Lasiurus cinereus cinereus (Palisot de Beauvois) (hoary bat)				x	
Plecotus townsendii pallescens (Miller) (Townsend's bat)					x
Eptesicus fuscus pallidus Young (big brown bat)				x	
	Order Lagomorpha Family Leporidae — Rabbits and Hares				
Sylvigagus nuttallii grangeri (J.A. Allen) (Nuttall's cottontail)					x
Sylvilagus audubonni baileyi (Merriam) (desert cottontail)		x			
Lepus townsendii campanius Hollister (white-tailed jackrabbit)		x			
Lepus californicus melanotis Mearns (black-tailed jackrabbit)					x
	Order Rodentia Family Sciuridae — Squirrels				
Eutamias minimus pallidus (J.A. Allen) (least chipmunk)		x			
Spermophilus tridecemlineatus pallidus J.A. Allen (thirteen-lined ground squirrel)		x			
Cynomys ludovicianus ludovicianus (Ord) (black-tailed prairie dog)		x			
	Family Geomyidae — Pocket gophers				
Thomomys talpoides attenuatus Hall & Montague			x		
Thomomys talpoides bullatus V. Bailey (northern pocket gopher)			x		
Geomys bursarius lutescens Merriam (plains pocket gopher)					x
	Family Heteromyidae — Pocket mice and kangaroo rats				
Perognathus fasciatus olivaceogriseus Swenk (olive-backed pocket mouse)		x			
Perognathus flavus piperi Goldman (silky pocket mouse)				x	
Perognathus hispidus paradoxus Merriam (hispid pocket mouse)					x
Dipodomys ordii priscus Hoffmeister		x			
Dipodomys ordii terrosus Hoffmeister (Ord's kangaroo rat)		x			
	Family Castoridae — Beavers				
Castor canadensis missouriensis Bailey (beaver)					x
	Family Cricetidae — Cricetids				
Reithrodontomys montanus albescens Cary (plains harvest mouse)					x
Reithrodontomys megalotis dychei J.A. Allen (western harvest mouse)		x			
Peromyscus maniculatus nebrascensis (Coues) (deer mouse)		x			
Peromyscus leucopus aridulus Osgood					x
Onychomvs leucogaster arcticeps Rhoads		x			
Onychomys leucogaster missouriensis (Audubon and Bachman) (northern grasshopper mouse)					x
Neotoma cinerea orolestes Merriam (bushy-tailed wood rat)					x
Microtus pennsylvanicus insperatus (J.A. Allen) (Meadow vole)		x			
Microtus longicaudus longicaudus (Merriam) (long-tailed vole)					x
Microtus ochrogaster haydenii (Baird) (prairie vole)				x	
Lagurus curtatus levidensis (Goldman) (sagebrush vole)		x			
Ondatra zibethicus cinnamominus (Hollister) (muskrat)				x	

(continued next page)

Species	Taxonomic Rank	Best Information Available[a] Observed[b]	Signs[c]	Local Records[d]	Possible[e]
	Family Muridae – Murids				
Mus musculus domesticus Rutty (house mouse)					x
	Family Erethizontidae – Porcupines				
Erethizon dorsatum bruneri Swenk (porcupine)		x			
	Order Carnivora – Carnivores Family Canidae – Canids				
Canis latrans latrans Say (coyote)		x			
Vulpes vulpes regalis Merriam (red fox)		x			
Vulpes velox velox (say) (swift fox)					x
Urocyon cinerreoargenteus ocythous Bangs (gray fox)					x
	Family Procyonidae – Procyonids				
Procyon lotor hirtus Nelson & Goldman (raccoon)		x			
	Family Mustelidae – Mustelids				
Mustela erminea muricus (Bangs) (ermine)					x
Mustela frenata nevadensis Hall (long-tailed weasel)				x	
Mustela vison letifera Hollister (mink)					x
Taxidea taxus taxus (Schreber) (badger)		x			
Mustela nigripes (Audubon & Bachman) (black-footed ferret)					x
Spilogale putorius interrupta (Rafinesque) (spotted skunk)					x
Mephitis mephitis hudsonica Richardson (striped skunk)		x			
	Family Felidae – Cats				
Lynx rufus pallescens Merriam (bobcat)		x			
	Order Artiodactyla – Artiodactyls Family Cervidae – Deer				
Cervus canadensis nelsoni V. Bailey (American elk)		x			
Odocoileus hemionus hemionus (Rafinesque) (mule deer)		x			
Odocoileus virginianus ochrourus V. Bailey (white-tailed deer)					x
	Family Antilocapridae – Pronghorn				
Antilocapridae americana americana (Ord) (pronghorn)		x			

(a) After each species an "x" is marked to indicate only the best information currently available. Four sources of evidence for a species' presence in the area, ranked according to their degree of certainty include:

(b) Species actually seen on or near one or more study areas by ECI personnel.

(c) Unmistakable field signs of the species (tracks, scats, burrows, etc.) observed by ECI personnel.

(d) Specimens recorded in the literature were taken and preserved from the immediate vicinity of one or more study areas.

(e) Judgment based upon species range-maps and habitat descriptions (Long, C.A. 1965. The mammals of Wyoming. University of Kansas Publications, Museum of Natural History. 14:493-758).

Although domestic livestock are not part of the native fauna, they do exert an important impact on the vegetation of this region and also directly affect use by various types of native fauna. The mine area and east plant site are both within the area regulated by the Thunder Basin Grazing Association. Data obtained from Mr. Ed Coy, of the Thunder Basin National Grassland Department of Range Management, U.S. Forest Service, in Douglas (personal communication), indicate that recent stocking rates for the association have averaged about 11 acres per animal per month (11 acres per cow per month or 2.2 acres per sheep per month). However, the total area involved includes

substantial areas of very rough breaks with low carrying capacities. Thus, the Teckla Community Allotment within the Thunder Basin Association might be considered as more representative of the upland conditions on the mine lease area. Stocking rates on this allotment have averaged about 4 to 5 acres per animal unit month or 50 to 55 acres for each cow per year and 10 to 12 acres for each sheep per year. Use of the allotment is about evenly divided between sheep and cattle.

While this information is for the Rochelle mine area and east plant site, similar stocking rates are probably practiced at the south plant site as well.

h. Birds

1) Methods

Two procedures were employed to census species of birds on the Rochelle mine area and the south and east plant sites. At all sites standardized roadside censuses, similar to those used in the nationwide Breeding Bird Surveys of the U.S. Fish and Wildlife Service, were conducted. These roadside censuses provide an index of relative abundance of birds found in the spectrum of habitats at each of the three areas of concern. Routes in the Rochelle Mine vicinity consisted of 30 stops, spaced 0.5 miles apart, along a prescribed route which followed existing roadways or went overland where necessary. At each stop, all birds seen or heard within an 0.25 mile radius over a 3-minute recording period were tallied. In June and December, the route was censused on consecutive days. At the north and south plant sites, 20 stops were censused over three consecutive days in September. Censuses commenced at first morning light.

In June, tallies of individuals detected per unit of effort under closely standardized conditions were made on three consecutive days within three vegetation types representative of the Rochelle mine area. Tracts censused corresponded to small mammal trap locations 1, 3 and 4. In this procedure, the censuser entered a plot and slowly traversed parallel, linear transects, recording all individuals flushed or observed on the ground along each transect. This procedure occupied one hour at each tract to determine relative abundance of breeding species within each of the three prominent habitats. Transient flocks of birds and wide-ranging raptors were not tallied during this time, but were recorded during reconnaissance surveys.

The three mine area habitats were recensused on December 8, 1973, to determine use by winter residents; a pine stand within the Rochelle Hills was also censused on that day. This technique is impractical during migration periods and, therefore, was not employed at the south and east plant site areas in September.

2) Results

Results of the roadside bird censuses on the Rochelle mine area are presented in table A-54 (June) and A-55 (December). Those for the plot censuses are given in tables A-56 (June) and A-57 (December). Results of the roadside censuses at the east and south plant sites in September are presented in tables A-58 and A-59, respectively. Table A-60 lists all bird species sighted on the three study tracts and all other species expected to use the region for winter habitat, breeding habitat, and during migration periods.

Table A-54. Numbers and relative abundance of birds tallied on three roadside censuses at the Rochelle mine area (June 22-24, 1973)

Species	Number of stops recorded for species[a]	Percent of total stops	Total individuals observed	Average number of individuals per stop[b]	Relative abundance[c]
Lark bunting	61	77.2	267	3.38	25.1
Western meadowlark	75	94.9	244	3.09	22.9
Horned lark	52	65.8	180	2.28	16.9
Brewer's sparrow	57	72.1	133	1.68	12.5
Vesper sparrow	30	38.0	51	0.64	4.8
Mourning dove	22	27.8	44	0.56	4.1
McCown's longspur	12	15.2	33	0.42	3.1
Red-winged blackbird	13	16.5	29	0.37	2.7
Killdeer	12	15.2	20	0.25	1.9
Night hawk	6	7.6	13	0.16	1.2
Chestnut-collared longspur	7	8.9	8	0.10	0.8
Lark sparrow	6	7.6	6	0.08	0.6
Rufous-sided towhee	5	6.3	5	0.06	0.5
Robin	4	5.1	4	0.05	0.4
Marsh hawk	3	3.8	4	0.05	0.4
Sage thrasher	3	3.8	3	0.04	0.3
Rock wren	2	2.5	3	0.04	0.3
Great-horned owl	2	2.5	2	0.02	0.2
Ferruginous hawk	2	2.5	2	0.02	0.2
Say's phoebe	2	2.5	2	0.02	0.2

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Species	Number of stops recorded for species[a]	Percent of total stops	Total individuals observed	Average number of individuals per stop[b]	Relative abundance[c]
Mallard	2	2.5	2	0.02	0.2
Poorwill	1	1.3	1	0.01	0.1
Chipping sparrow	1	1.3	1	0.01	0.1
Kestrel	1	1.3	1	0.01	0.1
Starling	1	1.3	1	0.01	0.1
Sage grouse	1	1.3	1	0.01	0.1
Swainson's hawk	1	1.3	1	0.01	0.1
Cliff swallow	1	1.3	1	0.01	0.1
Barn swallow	1	1.3	1	0.01	0.1
Golden eagle	1	1.3	1	0.01	0.1
Upland plover	1	1.3	1	0.01	0.1
Total			1,065		100.3

(a) A stop consisted of a three minute period during which all birds seen or heard by the observer were recorded. The total number of stops over a three day period was 79, distributed as: 19 on June 22, 30 on June 23, and 30 on June 24, along a 15-mile transect.

(b) Averaged over three daily transects.

(c) Percent relative abundance for each species = $\frac{\text{total observed individuals of this species}}{\text{total observed individual of all species}} \times 100\%$.

Table A-55. Numbers and relative abundance of birds tallied on two roadside censuses at the Rochelle mine area, (December 8-9, 1973)[a]

Species	Number of stops recorded for species	Percent of total stops	Total individuals observed	Average number of individuals per stop	Relative abundance
Golden eagle	18	30.0	27	1.04	65.8
Horned lark	3	5.0	9	0.35	22.0
Marsh hawk	3	5.0	3	0.12	7.3
Red-tailed hawk	2	3.3	2	0.08	4.9
Total			41		100.0

(a) See table A-54 for clarification of table headings.

Table A-56. Numbers and relative abundance of birds tallied on three roadside censuses at the east plant site, (September 28-30, 1973)[a]

Species	Number of stops recorded for species[b]	Percent of total stops	Total individuals observed	Average number of individuals per stop	Relative abundance
Western meadowlark	43	71.7	328	5.47	45.8
Horned lark	23	38.3	87	1.45	12.1
Sage thrasher	27	45.0	39	0.65	5.4
Starling	6	10.0	37	0.62	5.2
Vesper sparrow	22	36.7	36	0.60	5.0
Black-billed magpie	14	23.3	22	0.37	3.1
Mourning dove	10	16.7	20	0.33	2.8
Brewer's sparrow	13	21.7	16	0.27	2.2
Mountain bluebird	7	11.7	16	0.27	2.2
Blacked-capped chickadee	6	10.0	15	0.25	2.1
Blue-winged teal	3	5.0	13	0.22	1.8
Common crow	1	1.7	13	0.22	1.8
Red-breasted nuthatch	8	13.3	12	0.20	1.7
Common grackle	3	5.0	9	0.15	1.3
Oregon junco	3	5.0	8	0.13	1.1
Robin	5	8.3	7	0.12	1.0
Rufous-sided towhee	2	3.3	6	0.10	0.8
Marsh hawk	4	6.7	4	0.07	0.6
Western kingbird	3	5.0	4	0.07	0.6
Western wood pewee	2	3.3	4	0.07	0.6

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Species	Number of stops recorded for species(b)	Percent of total stops	Total individuals observed	Average number of individuals per stop	Relative abundance
MacGillivray's warbler	1	1.7	4	0.07	0.6
Red-shafted flicker	1	1.7	4	0.07	0.6
Golden eagle	3	5.0	3	0.5	0.4
Sage sparrow	2	3.3	3	0.05	0.4
Brewer's blackbird	1	1.7	3	0.05	0.4
Lark bunting	1	1.7	1	0.02	0.1
Lark sparrow	1	1.7	1	0.02	0.1
Great blue heron	1	1.7	1	0.02	0.1
Belted kingfisher	1	1.7	1	0.02	0.1
Total			717		100.0

(a) See table A-54 for clarification of table headings.

(b) The number of stops was 20 per day over a three day period for a total of 60 stops.

Table A-57. Numbers and relative abundance of birds tallied on three roadside censuses at the south plant site (October 1-3, 1973)(a)

Species	Number of stops recorded for species(b)	Percent of total stops	Total individuals observed	Average number of individuals per stop	Relative abundance
Horned lark	51	85.0	1020	17.00	66.8
Western meadowlark	42	70.0	303	5.05	19.8
Vesper sparrow	33	55.0	102	1.70	6.7
Western kingbird	13	21.7	54	0.57	3.5
Brewer's blackbird	1	1.7	20	0.33	1.3
Marsh hawk	6	10.0	6	0.10	0.4
Sage thrasher	4	6.7	4	0.07	0.3
Golden eagle	2	3.3	4	0.07	0.3
Brewer's sparrow	2	3.3	4	0.07	0.3
Sage grouse	2	3.3	4	0.07	0.3
Prairie falcon	2	3.3	3	0.05	0.2
Mourning dove	2	3.3	3	0.05	0.2
Common nighthawk	1	1.7	1	0.02	0.1
Total			1528		100.2

(a) See table A-54 for clarification of table headings.

(b) The number of stops was 20 per day over a three day period for a total of 60 stops.

Table A-58. Numbers and relative abundance of birds censused by the direct count method in three habitats on the Rochelle mine area (June, 1973)

Area	Species	NUMBER OBSERVED ON 22 June	23 June	24 June	Total	Relative abundance	Mean, number per day
PLOT 1 (scattered sagebrush)	Brewer's sparrow	22	9	27	58	39.5	19.3
	Lark bunting	12	11	15	38	25.8	12.7
	Horned lark	13	13	10	36	24.5	12.0
	Vesper sparrow	1	6	2	9	6.1	3.0
	Western meadowlark	1	2	3	6	4.1	2.0
	Total	49	41	57	147	100.0	
PLOT 4 (heavy sagebrush)	Brewer's sparrow	27	20	23	70	38.2	23.3
	Lark bunting	23	4	17	44	24.1	14.6
	Western meadowlark	17	9	12	38	20.8	12.6
	Horned lark	6	5	6	17	9.3	5.6
	Vesper sparrow	4	5	5	14	7.6	4.6
	Total	77	43	63	183	100.0	
PLOT 3 (grassland)	Horned lark	19	10	17	46	36.8	15.3
	Lark bunting	12	8	14	34	27.2	11.3
	Western meadowlark	11	5	13	29	23.2	9.7
	Brewer's sparrow	4	1	3	8	6.4	2.6
	Vesper sparrow	1	1	1	3	2.4	1.0
	Mallard	1	1	1	3	2.4	1.0
	Grasshopper sparrow	–	1	1	2	1.6	0.3
	Total	48	27	50	125	100.0	

Table A-59. Numbers and relative abundance of birds censused by direct count method in four habitats on the Rochelle mine area (December, 1973)

Area	Species	Number Observed, December 8	Total	Relative Abundance
PLOT 1 (scattered sagebrush)	No species flushed	–	–	–
PLOT 4 (heavy sagebrush)	No species flushed	–	–	–
PLOT 3 (grassland)	No species flushed	–	–	–
PLOT 5 (rough breaks – scattered pines)	Slate-colored junco	1	1	50.0
	Red-breasted nuthatch	1	1	50.0
	Total	2	2	100.0

Table A-60. Bird species observed by ECI personnel, reported by local bird watchers and anticipated to occur in habitats of the Rochelle mine area and the south and east plant sites[a]

Order/Family	Species[b] Common Name	Scientific Name	Expected Residence Status[c]	Expected Abundance[d]
PODICIPEDIFORMES (Grebes)	Eared grebe	*Podiceps nigricollis*	M	U
	Western grebe	*Aechmophorus occidentalis*	M	U
	Pied-billed grebe	*Podilymbus podiceps*	S	U
CICONIIFORMES (Herons, Ibises)	*Great blue heron	*Ardea herodias*	S	U
	Black-crowned night heron	*Nycticorax nycticorax*	S	U
	White-faced ibis	*Plegadis chihi*	M	R
ANSERIFORMES (Waterfowl)	Canada goose	*Branta candensis*	M	U
	Snow goose	*Chen caerulescens*	M	U
	*Mallard	*Anas playrhynchos*	R	C
	*Gadwall	*Anas strepera*	R	U
	*Pintail	*Anas acuta*	M	F.C.
	Green-winged teal	*Anas crecca*	M	U
	*Blue-winged teal	*Anas discors*	S	F.C.
	Cinnamon teal	*Anas cyanoptera*	S	U
	*American wigeon	*Anas americana*	M	U
	Northern shoveler	*Anas clypeata*	S	U
	Redhead	*Aythya americana*	S	U
	Ring-necked duck	*Aythya collaris*	M	U
	Canvasback	*Aythya valisineria*	S	R
	Lesser scaup	*Aythya affinis*	M	F.C.
	Common goldeneye	*Bucephala clangula*	M	U
	Ruddy duck	*Oxyura jamaicensis*	S	R
	Common merganser	*Mergus merganser*	W	R
FALCONIFORMES (Vultures, Hawks, Falcons)	*Turkey vulture	*Cathartes aura*	S	U
	Sharp-shinned hawk	*Accipiter striatus*	R	U
	Cooper's hawk	*Accipiter cooperii*	R	U
	*Red-tailed hawk	*Buteo jamaicensis*	R	F.C.
	*Swainson's hawk	*Buteo swainsoni*	S	C
	*Rough-legged hawk	*Buteo lagopus*	W	C
	*Ferruginous hawk	*Buteo regalis*	S	C
	*Golden eagle	*Aquila chrysaetos*	R	C
	*Bald eagle	*Haliaeetus leucocephalus*	W	R
	*Marsh hawk	*Circus cyaneus*	R	C
	Gyrfalcon	*Falco rusticolus*	W	R
	*Prairie falcon	*Falco mexicanus*	R	F.C.
	Peregrine falcon	*Falco peregrinus*	M	R
	Merlin	*Falco columbarius*	W	U
	*American kestrel	*Falco sparverius*	R	C
GALLIFORMES (gallinaceous birds)	*Sage grouse	*Centrocercus urophasianus*	R	F.C.
	+Sharp-tailed grouse	*Pedioecetes phasianellus*	R	U
	+Chukar	*Alectoris chukar*	R	R
GRUIFORMES (cranes and their allies)	Sandhill crane	*Grus canadensis*	M	U
	Sora	*Porzana carolina*	S	U
	American coot	*Fulica americana*	R	F.C.

(continued next page)

Order/Family	Species(b) Common Name	Scientific Name	Expected Residence Status(c)	Expected Abundance(d)
CHARADRIIFORMES (Shorebirds, gulls, etc.)	*Killdeer	*Charadrius vociferus*	S	C
	Mountain plover	*Charadrius montana*	S	R
	Long-billed curlew	*Numenius americanus*	S	U
	Whimbrel	*Numenius phaeopus*	M	R
	*Upland plover	*Bartramia longicauda*	S	R
	Spotted sandpiper	*Actitis macularia*	S	U
	Solitary sandpiper	*Tringa solitaria*	M	F.C.
	Willet	*Catoptrophorus semipalmatus*	M	U
	Greater yellow legs	*Tringa melanoleucus*	M	U
	Lesser yellow legs	*Tringa flavipes*	M	U
	Pectoral sandpiper	*Calidris melanotos*	M	U
	Baird's sandpiper	*Calidris bairdii*	M	F.C.
	Least sandpiper	*Calidris minutilla*	M	F.C.
	Long-billed dowitcher	*Limnodramus scolopaceus*	M	F.C.
	Semipalmated sandpiper	*Caldris pusillus*	M	U
	Western sandpiper	*Calidris mauri*	M	U
	Marbled godwit	*Limosa fedoa*	M	F.C.
	Hudsonian godwit	*Limosa haemastica*	M	R
	American avocet	*Recurvirostra americana*	M	F.C.
	*Wilson's phalarope	*Steganopus tricolor*	S	F.C.
	Northern phalarope	*Lobipes lobatus*	M	F.C.
	California gull	*Larus californicus*	S	U
	Ring-billed gull	*Larus delawarensis*	S	U.C.
	*Franklin's gull	*Larus pipixcan*	M	A
	Forster's tern	*Sterna forsteri*	S	U
	Least tern	*Sterna albifrons*	S	R
	Black tern	*Chlidonias niger*	S	U
CUCULIFORMES (Cuckoos)	Yellow-billed cuckoo	*Coccyzus americanus*	S	U
COLUMBIFORMES (Pigeons and doves)	*Rock dove	*Columba livia*	R	C
	*Mourning dove	*Zenaida macroura*	S	C
STRIGIFORMES (Owls)	Barn owl	*Tyto alba*	S	R
	*Great horned owl	*Bubo virginianus*	R	F.C.
	Snowy owl	*Nyctea scandiaca*	W	R
	Burrowing owl	*Speotyto cunicularia*	S	U
	Long-eared owl	*Asio otus*	R	R
	Short-eared owl	*Asio flammeus*	R	U
CAPRIMULGIFORMES (Goatsuckers)	*Poorwill	*Phalaenoptilus nuttallii*	S	U
	*Common nighthawk	*Cherdeiles minor*	S	C
APODIFORMES (Swifts, hummingbirds)	Broad-tailed hummingbird	*Selasphorus platycercus*	S	U
CORACILFORMES (Kingfishers)	*Belted kingfisher	*Megaceryle alcyon*	R	U
PICIFORMES (Woodpeckers)	*Common flicker	*Colaptes auratus*	R	C
	+Red-headed woodpecker	*Melanerpes erythrocephalus*	S	U
	Hairy woodpecker	*Dendrocopos villosus*	R	U
	Downy woodpecker	*Dendrocpos pubescens*	R	U
PASSERIFORMES (Perching birds) Family: Tyrannidae (tyrant flycatchers)	+Eastern kingbird	*Tyrannus tyrannus*	S	U
	*Western kingbird	*Tyrannus verticalis*	S	C
	Cassin's kingbird	*Tyrannus vociferans*	S	R
	*Say's phoebe	*Sayornis saya*	S	C
	Western flycatcher	*Empidonax difficilis*	M	U
	*Western wood pewee	*Contopus sordidulus*	S	C
	Olive-sided flycatcher	*Nuttallornis horealis*	M	R
Family: Alaudidae (larks)	*Horned lark	*Eremophilia alpestris*	R	A

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Order/Family	Species[b] Common Name	Scientific Name	Expected Residence Status[c]	Expected Abundance[d]
Family: Hirundinidae (swallows)	Tree swallow	*Iridoprocne bicolor*	M	U
	Rough-winged swallow	*Stelgidopteryx ruficollis*	S	U
	+Bank swallow	*Riparia riparia*	S	F.C.
	*Barn swallow	*Mirundo rustica*	S	C
	*Cliff swallow	*Petrochelidon pyrrhonota*	S	F.C.
	Purple martin	*Progne subis*	S	R
Family: Corvidae (jays, magpies and crows)	Blue Jay	*Cyanocitta cristata*	R	U
	Pinyon jay	*Gymnorhinus cyanocephalus*	R	R
	*Black-billed magpie	*Pica pica*	R	C
	*Common crow	*Corvus brachyrhynchos*	R	F.C.
Family: Paridae (chickadees, titmice, etc.)	*Black-capped chickadee	*Parus atricapillus*	R	C
Family: Sittidae (nuthatches)	*Red-breasted nuthatch	*Sitta canadensis*	W	U
Family: Troglodytidae (wrens)	*House wren	*Troglodytes aedon*	S	C
	*Rock wren	*Salpinctes obsoletus*	S	C
Family: Mimidae (mockingbirds and thrashers)	+Mockingbird	*Mimus polyglottos*	S	U
	Gray catbird	*Dumetella carolinensis*	S	U
	Brown thrasher	*Toxostoma rufum*	S	U
	*Sage thrasher	*Oreoscoptes montanus*	S	C
Family: Turdidae (thrushes, solitaires, and bluebirds)	*American robin	*Turdus migratorius*	S	C
	Hermit thrush	*Catharus gutatus*	M	U
	+Swainson's thrush	*Catharus ustulatus*	M	F.C.
	Veery	*Catharus fuscescens*	M	R
	*Mountain bluebird	*Sialia currucoides*	S	C
	Townsend's solitaire	*Myadestes townsendi*	M	U
Family: Motacillidae (pipits and wagtails)	Sprague's pipit	*Anthus spragueii*	M	R
Family: Bombycillidae (waxwings)	Bohemian waxwing	*Bombycilla garrulus*	W	U
	Cedar waxwing	*Bombycilla cedrorum*	R	R
Family: Laniidae (shrikes)	Northern shrike	*Lanius excubitor*	W	F.C.
	*Loggerhead shrike	*Lanius ludovicianus*	S	C
Family: Sturnidae (starlings)	+Starling	*Sturnus vulgaris*	R	C
Family: Vireonidae (vireos)	Red-eyed vireo	*Vireo olivaceus*	S	R
	Warbling vireo	*Vireo gilvus*	M	R
Family: Parulidae (warblers)	Orange-crowned warbler	*Vermivora celata*	M	F.C.
	Virginia's warbler	*Vermivora virginiae*	M	F.C.
	Yellow warbler	*Dandroica petechia*	S	U
	Yellow-rumped warbler	*Dendroica coronata*	M	C
	+Townsend's warbler	*Dendroica townsendi*	M	R
	Chestnut-sided warbler	*Dendroica pensulvanica*	M	R
	Blackpoll warbler	*Dendroica striata*	M	R
	Northern water thrush	*Seiurus noveboracensis*	M	R
	*MacGillivray's warbler	*Oporornis tolmeii*	S	U
	+Common yellow throat	*Geothypis trichas*	S	U
	Wilson's warbler	*Wilsonia pusilla*	M	C
	Canada warbler	*Wilsonia canadensis*	M	R
	+American redstart	*Setophaga ruticilla*	M	U
Family: Ploceidae (weaver finches)	*House sparrow		R	U

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Order/Family	Species[b] Common Name	Scientific Name	Expected Residence Status[c]	Expected Abundance[d]
Family: Icteridae		*Passer domesticus*		
(blackbirds, orioles,	*Western meadowlark	*Sturnella neglecta*	R	C
etc.)	+Red-winged blackbird	*Agelaius phoeniceus*	R	C
	+Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	S	U
	Orchard oriole	*Icterus spurius*	S	U
	*Northern oriole	*Icterus galbula*	S	C
	*Brewer's blackbird	*Euphagus cyanocephalus*	S	C
	Common grackle	*Quiscalus guiscula*	S	F.C.
	Brown-headed cowbird	*Molothrus ater*	S	U
Family: Thraupidae (tanagers)	Western tanager	*Piranga ludoviciana*	M	R
Family: Fringillidae (grosbeaks, finches, sparrows and buntings)	+Black-headed grosbeak	*Pheucticus melanocephalus*	S	R
	+Evening grosbeak	*Hesperiphona vespertina*	R	R
	Blue grosbeak	*Guiraca caerulea*	S	R
	+Lazuli bunting	*Passerina amoena*	S	U
	Dickcissel	*Spiza americana*	S	R
	House finch	*Carpodacus mexicanus*	R	U
	*Gray-crowned rosy finch	*Leucosticte tephrocotis*	W	R
	Purple finch	*Carpodacus purpureus*	W	R
	Black rosy finch	*Leucosticte atrata*	W	R
	Common redpoll	*Acanthis flammea*	W	F.C.
	Pine siskin	*Spinus pinus*	R	U
	+American goldfinch	*Spinus tristis*	R	U
	Red crossbill	*Loxia curvirostra*	W	R
	Green-tailed towhee	*Chlorura chlorura*	M	U
	*Rufous-sided towhee	*Pipilo erythrophthalmus*	S	C
	*Lark bunting	*Calamospiza melanocorys*	S	A
	Savannah sparrow	*Passerculus sandwichensis*	S	U
	*Grasshopper sparrow	*Ammodramus savannarum*	S	F.C.
	Baird's sparrow	*Ammondramus bairdii*	M	R
	*Vesper sparrow	*Pooecetes gramineus*	S	C
	*Lark sparrow	*Chondestes grammacus*	S	C
	Cassin's sparrow	*Aimophila cassinii*	S	U
	Black-throated sparrow	*Amphispiza bilineata*	M	R
	*Sage sparrow	*Amphispiza belli*	S	U
	*Dark-eyed junco	*Junco hyemalis*	W	C
	Gray-headed junco	*Junco caniceps*	W	U
	+Tree sparrow	*Spizella arborea*	W	U
	*Chipping sparrow	*Spizella passerina*	S	F.C.
	Clay-colored sparrow	*Spizella pallida*	M	F.C.
	*Brewer's sparrow	*Spizella breweri*	S	A
	Harris's sparrow	*Zonotrichia querula*	M	R
	White crowned sparrow	*Zonotrichia leucophrys*	W	U
	Lincoln's sparrow	*Melospiza lincolnii*	M	R
	Song sparrow	*Melospiza melodia*	R	U
	*McCown's longspur	*Calcarius mccownii*	S	C
	Lapland longspur	*Calcarius lapponicus*	W	F.C.
	Chestnut-collared longspur	*Calcarius ornatus*	S	F.C.

(a) Anticipated species generally are those which might appear during migration or at times when censusing was not undertaken. (Interpreted from Pawnee National Grassland records of U.S. IBP Grassland Biome censuses.)

(b) Listed according to the Checklist of North American Birds. 1957. Fifth ed. American Ornithologists' Union (as revised in the thirty-second supplement, 1973). (Eisenmann, E. 1973. Thirty-second supplement to the American Ornithologists' Union check-list of North American birds. The Auk. 90:411-419.)

(c) Expected residence status: R = year-round resident; M = migrant; W = winter visitor; S = summer visitor, including breeding species which migrate to and from the area each year.

(d) Expected abundance: A = abundant; C = common; F.C. = fairly common; U = uncommon; and R = rare.

* Species observed by ECI personnel

\+ Species reported by local bird watchers

i. Invertebrates

1) Methods

Terrestrial invertebrates (primarily insects and spiders) were collected at the mine vicinity during June and at the south and east plant sites during September. Representative examples of each vegetation type which was sampled for mammals were concurrently sampled for invertebrates (see figures A-3 through A-5). These included heavy sagebrush, scattered sagebrush-grass mixtures, grasslands, cottonwood bottoms, and stands of ponderosa pine. Sorting and preliminary identifications have been completed in the laboratory, and specimens of the 10 most abundant species have been sent to the Smithsonian Institute for verification of identification.

At each site standardized sweep netting was used as the major means of collecting insects. Each sample consisted of 50 full sweeps and four such samples were collected at each study site along randomly located transects. Specimens were killed in sodium cyanide killing jars and preserved in 70 percent isopropyl alcohol.

Ground-dwelling species were sampled at the mine area with pitfall traps. The traps consisted of jars inserted flush to their lips in the ground and containing a small quantity of glycerine. These pitfalls were placed in each vegetation type at 50 ft. intervals, left for 5 days, retrieved, and then their contents removed and preserved in alcohol. Flying insects and other forms not likely to be taken by the above techniques were captured opportunistically with an aerial net, and preserved.

2) Results

Invertebrates collected by sweep sampling at the Rochelle mine area in June are listed in tables A-61 through A-63 for the three vegetation types sampled. Results of the pitfall sampling in the same vegetation types are presented in tables A-64 through A-66. Invertebrates collected in sweep samples at the east plant site in four vegetation types are listed in tables A-67 through A-70, while those collected in sweep samples from two vegetation types at the south plant site are listed in tables A-71 and A-72. Although most insect sampling locations corresponded to mammal sampling locations, an exception appears in table A-71 where an additional sample from an abandoned hayfield was deemed appropriate. Results of August, 1973 sweep samples collected on the Rochelle mine site are shown in tables A-73 through A-75. Table A-76 summarizes invertebrate diversity and equitability as useful measures of ecosystem diversity and stability in different seasons on the Rochelle mine area and the south and east plant sites.

Table A-61. Results of invertebrate sweep sampling in scattered sagebrush on the Rochelle mine area (June, 1973)

Order and Family	Common Name	Most abundant species[a]	Number of species groups	Total number of individuals
COLLEMBOLA				
Sminthuridae	Globular springtails	1	1	31
	Order total			31
ORTHOPTERA				
Acrididae	Short-horned grasshoppers		7	45
	Order total			45
PSOCOPTERA				
Psocidae	Common barklice		1	3
	Order total			3
THYSANOPTERA				
Thripidae	Common thrips		1	3
Phlaeothripidae	Tube-tailed thrips		2	2
Unknown	—		1	3
	Order total			8
HEMIPTERA				
Miridae	Plant bugs	2	8	61
Lygaeidae	Seed bugs		1	118
Coreidae	Leaf-footed bugs		1	9
Pentatomidae	Stink bugs		1	3
	Order total			191
HOMOPTERA				
Cicadellidae	Leafhoppers	2	16	151
Cercopidae	Froghoppers & spittlebugs		3	3
Delphacidae	Delphacid planthoppers	1	5	43
Psyllidae	Psyllids		1	2
Aphidae	Aphids	1	1	45
	Order total			244

(continued next page)

Order and Family	Common Name	Most abun-dant species[a]	Number of species groups	Total number of indi-viduals
COLEOPTERA				
Phalacridae	Shining flower beetles		1	1
Chrysomelidae	Leaf beetles		1	1
Unknown	—		1	1
	Order total			3
LEPIDOPTERA				
Larvae unknown	Moths		1	4
	Order total			4
DIPTERA				
Mycetophilidae	Fungus gnats		1	1
Asilidae	Robber flies		1	3
Chloropidae	Frit flies		4	24
	Order total			28
HYMENOPTERA				
Braconidae	Braconid wasps		2	7
Mymaridae	Fairyflies		1	4
Eulophidae	Eulophid wasps		2	6
Encyrtidae	Encyrtid wasps		1	6
Eupelmidae	Eupelmid wasps		1	3
Pteromalidae	Pteromalid wasps		2	7
Formicidae	Ants		4	57
	Order total			90
Total number of invertebrates in four samples				637

(a) Specimens representing the most abundant species in these groups have been sent to the Smithsonian Institution for positive identification.

Table A-62. Results of invertebrate sweep sampling in grasslands on the Rochelle mine area (June, 1973)

Order and Family	Common Name	Most abun-dant species[a]	Number of species groups	Total number of indi-viduals
COLLEMBOLA				
Sminthuridae	Globular springtail	1	1	821
	Order total			821
ORTHOPTERA				
Acrididae	Short-horned grasshoppers		6	153
	Order total			153
PSOCOPTERA				
Psocidae	Common barklice		1	2
	Order total			2
THYSANOPTERA				
Thripidae	Common thrips		1	5
Phlaeothripidae	Tube-tailed thrips		2	13
	Order total			18
HEMIPTERA				
Anthocoridae	Minute pirate bugs		1	1
Miridae	Plant bugs	3	6	482
Nabidae	Damsel bugs		1	59
Phymatidae	Ambush bugs		1	1
Tingidae	Lace bugs		1	1
Lygaeidae	Seed bugs	1	2	71
Coreidae	Leaf-footed bugs		1	5
Scutelleridae	Shield-backed bugs		1	1
Pentatomidae	Stink bugs		2	16
	Order total			635

(continued next page)

Order and Family	Common Name	Most abun-dant species[a]	Number of species groups	Total number of indi-viduals
HOMOPTERA				
Cicadellidae	Leafhoppers	2	16	346
Cercopidae	Froghoppers & spittlebugs		2	15
Delphacidae	Delphacid planthoppers	1	6	138
Aphididae	Aphids		2	42
	Order total			541
COLEOPTERA				
Elateridae	Click beetles		1	1
Curculionidae	Snout beetles (weevils)		1	1
	Order total			2
LEPIDOPTERA				
Adult unknown	Moths		1	17
	Order total			17
DIPTERA				
Ceratopogonidae	Biting midges		1	3
Cecidomyiidae	Gall gnats		1	4
Dolichopodidae	Long-legged flies		1	1
Sepsidae	Black scavenger flies		1	1
Chloropidae	Frit flies		3	21
Heleomyzidae	Heleomyzid flies		1	12
	Order total			43
HYMENOPTERA				
Braconidae	Braconid wasps		5	6
Mymaridae	Fairyflies		1	6
Trichogrammatidae	Trichogrammatids		1	21
Eulophidae	Eulophid wasps		1	16
Eupelmidae	Eupelmid wasps		1	1
Encyrtidae	Encyrtid wasps		3	9
Pteromalidae	Pteromalid wasps		2	2
Eurytomidae	Eurytomids or seed chalcids		1	1
Chalcididae	Chalcidid wasps		1	1
Formicidae	Ants		2	15
	Order total			78
Total number of invertebrates in four samples				2310

(a) Insects representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-63. Results of invertebrate sweep sampling in heavy sagebrush on the Rochelle mine area (June, 1973)

Order and Family	Common Name	Most abun-dant species[a]	Number of species groups	Total number of indi-viduals
COLLEMBOLA				
Sminthuridae	Globular springtails	1	1	57
	Order total			57
ORTHOPTERA				
Acrididae	Short-horned grasshoppers		5	48
Tettigoniidae	Long-horned grasshoppers		1	1
	Order total			49
THYSANOPTERA				
Thripidae	Common thrips		1	1
Phlaeothripidae	Tube-tailed thrips		2	6
Unknown	—		1	3
	Order total			10
HEMIPTERA				
Miridae	Plant bugs	2	10	207
Nabidae	Damsel bugs		1	1
Lygaeidae	Seed bugs	1	3	572
Coreidae	Leaf-footed bugs		1	19
Scutelleridae	Shield-backed bugs		1	1
Pentatomidae	Stink bugs		1	4
	Order total			804

(continued next page)

Order and Family	Common Name	Most abun-dant species[(a)]	Number of species groups	Total number of indi-viduals
HOMOPTERA				
Cicadellidae	Leafhoppers	1	18	213
Cercopidae	Froghoppers & spittlebugs		1	1
Delphacidae	Delphacid planthoppers	1	4	385
Fulgoridae	Fulgorid planthoppers		1	1
Psyllidae	Psyllids		1	17
Aphididae	Aphids	1	2	201
	Order total			818
COLEOPTERA				
Nitidulidae	Sap beetles		1	3
Mordellidae	Tumbling flower beetles		1	1
Curculionidae	Snout beetles (weevils)		1	1
Unknown	—		1	3
Larvae unknown	—		1	1
	Order total			9
LEPIDOPTERA				
Adult unknown	Moths		1	13
Immature unknown	—		1	1
	Order total			14
DIPTERA				
Ceratopogonidae	Biting midges		1	1
Chironomidae	Midges		1	4
Dolichopodidae	Long-legged flies		1	4
Pipinculidae	Big-headed flies		1	1
Chloropidae	Frit flies		5	34
Heleomyzidae	Heleomyzid flies		1	1
Tachinidae	Tachinid flies		1	3
	Order total			48
HYMENOPTERA				
Braconidae	Braconid wasps		4	11
Mymaridae	Fairyflies		1	11
Eulophidae	Eulophid wasps		3	25
Eupelmidae	Eupelmid wasps		1	20
Encyrtidae	Encyrtid wasps		4	7
Pteromalidae	Pteromalid wasps		5	8
Eurytomidae	Eurytomid or seed chalcids		1	16
Formicidae	Ants		4	31
	Order total			129
Total number invertebrates in four samples				1938

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-64. Results of invertebrate pitfall sampling in scattered sagebrush on the Rochelle mine area (June, 1973)

Order and Family	Common Name	Number of species groups	Total number of individuals
PHALLANGIDA	Harvestmen		27
	Order total		27
ARANEAE			
Lycosidae	Wolf spiders	1	4
	Order total		4
COLLEMBOLA			
Poduridae	Elongate-bodied springtails	2	66
Smithuridae	Globular springtails	2	234
	Order total		300
COLEOPTERA			
Carabidae	Ground beetles	5	11
Histeridae	Hister beetles	1	2
Silphidae	Carion beetles	1	1
Staphilinidae	Rove beetles	1	11
Dermestidae	Dermestid beetles	1	2
Elateridae	Click beetles	1	2
Tenebrionidae	Darkling beetles	5	6
Curculionidae	Snout beetles (weevils)	2	3
Unknown	—	1	2
	Order total		40
HYMENOPTERA			
Multillidae	Velvet ants	1	2
Formicidae	Ants	8	357
Unknown	—	1	1
	Order total		360
Total number of invertebrates in twelve pitfalls			731

Table A-65. Results of invertebrate pitfall sampling in grasslands on the Rochelle mine area (June, 1973)

Order and Family	Common Name	Number of species groups	Total number of individuals
PHALLANGIDA	Harvestmen		9
	Order total		9
ARANEAE			
Lycosidae	Wolf spiders		3
	Order total		3
COLLEMBOLA			
Sminthuridae	Globular springtails	2	315
	Order total		315
COLEOPTERA			
Cincindellidae	Tiger beetles	1	2
Carabidae	Ground beetles	6	21
Staphilinidae	Rove beetles	1	5
Elateridae	Click beetles	1	2
Curculionidae	Snout beetles (weevils)	1	1
	Order total		31
HYMENOPTERA			
Formicidae	Ants	7	214
	Order total		214
Total number of invertebrates in five pitfalls			572

Table A-66. Results of invertebrate pitfall sampling in heavy sagebrush on the Rochelle mine area (June, 1973)

Order and Family	Common Name	Number of species groups	Total number of individuals
PHALLANGIDA	Harvestmen		11
	Order total		11
ARANEAE			
Lycosidae	Wolf spiders		7
	Order total		7
COLLEMBOLA			
Poduridae	Elongate-bodied springtails	2	2
Sminthuridae	Globular springtails	1	80
	Order total		82
COLEOPTERA			
Carabidae	Ground beetles	1	31
Staphilinidae	Rove beetles	1	2
Tenebrionidae	Darkling beetles	2	13
Curculionidae	Snout beetles (weevils)	2	2
	Order total		48
HYMENOPTERA			
Formicidae	Ants	5	240
	Order total		240
Total number of invertebrates in five pitfalls			388

Table A-67. Results of invertebrate sweep sampling in scattered sagebrush on the east plant site (September, 1973)

Order and Family	Common Name	Most abundant species[a]	Number of species groups	Total Number of individuals
ARANEAE				
Araneidae	Orb weaver spiders	1	1	17
Thomisidae	Crab spiders		1	1
Salticidae	Jumping spiders		1	1
	Order total			19
ORTHOPTERA				
Acrididae	Short-horned grasshoppers	1	5	61
	Order total			61
HEMIPTERA				
Lygaeidae	Seed bugs		1	2
	Order total			2
HOMOPTERA				
Cicidellidae	Leafhoppers	5	11	184
Cercopidae	Froghoppers & spittlebugs		2	2
Delphacidae	Delphacid planthoppers		3	6
Aphididae	Aphids		3	8
	Order total			200
COLEOPTERA				
Phalacrididae	Shining flower beetles		1	1
Curculionidae	Snout beetles (weevils)		1	1
Unknown	–		1	1
	Order total			3
LEPIDOPTERA				
Larvae unknown	–		1	1
	Order total			1
DIPTERA				
Ceratopogonidae	Biting midges		1	2
Chironomidae	Non-biting midges		2	3
Dolichopodidae	Long-legged flies		1	2
Pipunculidae	Big-headed flies		1	1
Chloropidae	Frit flies	1	1	15
Anthomyiidae	Anthomyiid flies		1	1
Muscidae	Muscid flies		1	1
	Order total			25
HYMENOPTERA				
Eulophidae	Eulophid wasps		1	1
Encyrtidae	Encyrtid wasps		2	8
Cynipidae	Gall wasps		1	1
Formicidae	Ants	1	3	20
Unknown	–		2	2
	Order total			32
Total number of invertebrates in four samples				343

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

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Table A-68. Results of invertebrate sweep sampling in cottonwood bottomlands on the east plant site (September, 1973)

Order and Family	Common Name	Most abundant species[(a)]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders		2	5
Tetragnathidae	Grass spiders		1	6
Thomisidae	Crab spiders		2	5
	Order total			16
COLLEMBOLA				
Sminthuridae	Globular springtails		1	1
	Order total			1
ORTHOPTERA				
Acrididae	Short-horned grasshoppers		1	4
	Order total			4
PSOCOPTERA				
Psocidae	Common barklice		1	1
	Order total			1
HEMIPTERA				
Miridae	Plant bugs		1	4
Nabidae	Damsel bugs	1	2	19
Tingidae	Lace bugs		1	2
Lygaeidae	Seed bugs		1	2
	Order total			27
HOMOPTERA				
Cicadellidae	Leafhoppers	5	9	177
Cercopidae	Froghoppers & spittlebugs		2	3
Delphacidae	Delphacid planthoppers		3	6
Aphididae	Aphids		3	9
	Order total			129
COLEOPTERA				
Carabidae	Ground beetles		1	1
Staphylinidae	Rove beetles		1	2
Lathridiidae	Minute brown scavenger beetles		1	2
Coccinellidae	Ladybird beetles		1	1
Chrysomelidae	Leaf beetles		3	7
Unknown	–		1	2
	Order total			15
DIPTERA				
Culicidae	Mosquitoes		2	9
Ceratopogonidae	Biting midges	1	2	17
Chironomidae	Midges	1	3	53
Mycetophilidae	Fungus gnats		1	1
Dolichopodidae	Long-legged flies		2	3
Lonchopteridae	Spear-winged flies		1	2
Sepsidae	Black scavenger flies		1	10
Chloropidae	Frit flies		2	7
Anthomyiidae	Anthomyiid flies		2	4
Muscidae	Muscid flies		2	2
Unknown	–	1	1	21
	Order total			129
HYMENOPTERA				
Ichneumonidae	Ichneumonid wasps		1	1
Eulophidae	Eulophid wasps		1	1
Encyrtidae	Encyrtid wasps		1	1
Cynipidae	Gall wasps		4	4
Formicidae	Ants		4	14
	Order total			21
Total number of invertebrates in six samples				420

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-69. Results of invertebrate sweep sampling in rough breaks and scattered pines on the east plant site (September, 1973)

Order and Family	Common Name	Most abundant species[a]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders		1	1
Thomisidae	Crab spiders		1	1
	Order total			2
ORTHOPTERA				
Acrididae	Short-horned grasshoppers	1	4	15
	Order total			15
HEMIPTERA				
Miridae	Plant bugs		1	1
Nabidae	Damsel bugs		1	1
	Order total			2
HOMOPTERA				
Cicadellidae	Leafhoppers	1	11	36
Cercopidae	Froghoppers & spittlebugs		1	2
Aphididae	Aphids		1	1
	Order total			39
COLEOPTERA				
Staphylinidae	Rove beetles		1	2
Chrysomelidae	Leaf beetles		1	1
	Order total			3
LEPIDOPTERA				
Immature	Moths		1	1
	Order total			1
DIPTERA				
Chironomidae	Non-biting midges		1	1
Lonchopteridae	Spear-winged flies		1	1
Phoridae	Hump-backed flies		1	1
Sepsidae	Black scavenger flies		1	1
Chloropidae	Frit flies	1	3	12
Muscidae	Muscid flies (houseflies)		2	3
Unknown	—		1	3
	Order total			22
HYMENOPTERA				
Braconidae	Braconid wasps		1	1
Eulophidae	Eulophid wasps		1	1
Encyrtidae	Encyrtid wasps		2	2
Tiphiidae	Tiphiid wasps		1	1
Formicidae	Ants		1	3
	Order total			9
Total number of invertebrates in three samples				92

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification. Due to low total numbers at this site, only 3 species were included as most abundant.

Table A-70. Results of invertebrate sweep sampling in grassy bottomlands on the east plant site (September, 1973)

Order and Family	Common Name	Most abundant species[a]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders		1	1
Thomisidae	Crab spiders		1	1
	Order total			2
COLLEMBOLA				
Sminthuridae	Globular springtails		1	1
	Order total			1
HEMIPTERA				
Miridae	Plant bugs		1	1
Nabidae	Damsel bugs		1	2
Lygaeidae	Seed bugs		1	1
	Order total			4
HOMOPTERA				
Cicadellidae	Leafhoppers	2	5	283
Delphacidae	Delphacid planthoppers		1	3
Aphididae	Aphids		1	1
	Order total			287
COLEOPTERA				
Chrysomelidae	Leaf beetles		1	3
	Order total			3
DIPTERA				
Culicidae	Mosquitoes	1	1	21
Ceratopogonidae	Biting midges		1	1
Chironomidae	Non-biting midges		1	1
Sepsidae	Black scavenger flies		1	1
Chloropidae	Frit flies		2	15
Anthomyiidae	Anthomyiid flies		1	5
Muscidae	Muscid flies (houseflies)		1	1
Unknown	–		1	1
	Order total			46
HYMENOPTERA				
Braconidae	Braconid wasps		1	1
Mymaridae	Fairyflies		1	2
Eulophidae	Eulophid wasps		1	1
Encyrtidae	Encyrtid wasps		2	6
Eurytomidae	Seed chalcids		1	1
Formicidae	Ants	1	1	16
	Order total			27
Total number of invertebrates in four samples				370

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-71. Results of invertebrate sweep sampling in an abandoned field on the south plant site (September, 1973)

Order and Family	Common Name	Most abundant species[a]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders		1	1
Salticidae	Jumping spiders		1	1
	Order total			2
ORTHOPTERA				
Acrididae	Long-horned grasshoppers		4	7
	Order total			7
HEMIPTERA				
Miridae	Plant bugs		2	2
Nabidae	Damsel bugs		1	2
Lygaeidae	Seed bugs	1	1	15
Unknown	–		1	1
	Order total			20
HOMOPTERA				
Cicadellidae	Leafhoppers	1	5	44
Delphacidae	Delphacid planthoppers	1	2	13
Psyllidae	Psyllids		1	1
Aphididae	Aphids	1	3	30
	Order total			88
COLEOPTERA				
Coccinellidae	Ladybird beetles		1	1
Chrysomelidae	Leaf beetles	1	2	14
	Order total			15
LEPIDOPTERA				
Larvae unknown	Moths		1	10
	Order total			10
DIPTERA				
Chironomidae	Non-biting midges		2	8
Chloropidae	Frit flies		1	1
Anthomyiidae	Anthomyiid flies		1	6
	Order total			15
HYMENOPTERA				
Braconidae	Braconid wasps		1	1
Trichogrammatidae	Trichogrammatids		1	2
Encyrtidae	Encyrtid wasps		2	2
Pteromalidae	Pteromalid wasps		1	1
Formicidae	Ants		3	14
	Order total			20
Total number of invertebrates in four samples				177

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-72. Results of invertebrate sweep sampling in a sagebrush-hayfield mixture on the south plant site (September, 1973)

Order and Family	Common Name	Most abundant species[a]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders	1	1	10
Tetragnathidae	Grass spiders		1	1
Thomisidae	Crab spiders		2	4
Salticidae	Jumping spiders		1	1
	Order total			16
ORTHOPTERA				
Acrididae	Short-horned grasshoppers		3	7
	Order total			7
PSOCOPTERA				
Psocidae	Common barklice			1
	Order total			1
THYSANOPTERA				
Phlaeothripidae	Tube-tailed thrips		1	1
	Order total			1
HEMIPTERA				
Miridae	Plant bugs	2	4	45
Nabidae	Damsel bugs		1	2
Lygaeidae	Seed bugs	1	1	109
	Order total			156
HOMOPTERA				
Cicadellidae	Leafhoppers	3	11	65
Delphacidae	Delphacid planthoppers		3	11
Psyllidae	Psyllids		1	1
	Order total			77
COLEOPTERA				
Unknown	—		1	1
	Order total			1
LEPIDOPTERA				
Larvae	—	1	1	12
	Order total			12
DIPTERA				
Ceratopogonidae	Biting midges		1	4
Bombylliidae	Bee flies		1	4
Dolichopodidae	Long-legged flies		1	1
Chloropidae	Frit flies		1	1
Heleomyzidae	Heleomyzid flies		1	1
Anthomyiidae	Anthomyiid flies		1	5
Unknown	—		2	2
	Order total			18
HYMENOPTERA				
Braconidae	Braconid wasps		1	1
Formicidae	Ants		3	10
	Order total			11
Total number of invertebrates in four samples				300

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-73. Results of invertebrate sweep sampling in scattered sagebrush on the Rochelle mine area (August, 1973)

Order and Family	Common Name	Most abundant species[(a)]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders		2	9
Thomisidae	Crab spiders		4	15
Salticidae	Jumping spiders		2	7
Unknown (spiderlings)			1	1
	Order total			32
COLLEMBOLA				
Sminthuridae	Globular springtails		1	5
	Order total			5
ORTHOPTERA				
Acrididae	Short-horned grasshoppers	2	9	44
Tettigoniidae	Long-horned grasshoppers		1	1
Mantidae	Mantids		1	1
	Order total			46
THYSANOPTERA				
Phlaeothripidae	Tube-tailed thrips		1	5
	Order total			5
HEMIPTERA				
Miridae	Plant bugs		2	2
Lygaeidae	Seed bugs	1	1	26
Coreidae	Leaf-footed bugs		1	2
Pentatomidae	Stink bugs		1	1
	Order total			31
HOMOPTERA				
Cicadellidae	Leafhoppers	3	16	87
Cercopidae	Froghoppers & spittlebugs	1	2	17
Delphacidae	Delphacid planthoppers		4	14
Fulgoridae	Fulgorid planthoppers		1	1
Aphididae	Aphids		2	5
	Order total			124
COLEOPTERA				
Coccinellidae	Ladybird beetles		1	1
Cerculionidae	Snout beetles (weevils)		1	1
	Order total			2
LEPIDOPTERA				
Adult unknown	Moths		1	8
	Order total			8
DIPTERA				
Ceratopogonidae	Biting midges		1	1
Dolichopodidae	Long-legged flies		1	11
Pipunculidae	Big-headed flies		1	1
Chloropidae	Frit flies		1	5
Muscidae	Muscid flies		1	2
	Order total			20
HYMENOPTERA				
Mymaridae	Fairyflies		1	1
Eulophidae	Eulophid wasps		1	1
Encyrtidae	Encyrtid wasps		3	14
Pteromalidae	Pteromalid wasps		1	1
Cynipidae	Cynipids		1	1
Formicidae	Ants	1	1	81
Unknown	—		2	6
	Order total			105
Total number of invertebrates in four samples				378

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-74. Results of invertebrate sweep sampling in grasslands on the Rochelle mine area (August, 1973)

Order and Family	Common Name	Most abundant species[a]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders		1	5
Thomisidae	Crab spiders		4	24
Salticidae	Jumping spiders		2	7
Unknown (spiderlings)	–		1	5
	Order total			46
COLLEMBOLA				
Sminthuridae	Globular springtails	1	1	70
	Order total			70
ORTHOPTERA				
Acrididae	Short-horned grasshoppers		7	27
	Order total			27
THYSANOPTERA				
Phlaeothripidae	Tube-tailed thrips	1	2	28
Unknown	–		1	1
	Order total			29
HEMIPTERA				
Miridae	Plant bugs		1	13
Nabidae	Damsel bugs		2	11
Reduviidae	Assassin bugs		1	4
Phymatidae	Ambush bugs		1	1
Lygaeidae	Seed bugs		1	3
Scutelleridae	Shield-backed bugs		2	2
Pentatomidae	Stink bugs		1	1
Unknown	–			2
	Order total			38
HOMOPTERA				
Cicadellidae	Leafhoppers	2	8	73
Cercopidae	Froghoppers & spittlebugs		1	8
Delphacidae	Delphacid planthoppers		2	16
Fulgoridae	Fulgorid planthoppers		1	5
Aphididae	Aphids		2	2
	Order total			104
COLEOPTERA				
Chrysomelidae	Ladybird beetles		1	1
Curculionidae	Snout beetles (weevils)		1	1
	Order total			2
NEOROPTERA				
Hemerobiidae	Brown lacewings		1	2
	Order total			2
LEPIDOPTERA				
Adult	Moths		1	5
	Order total			5
DIPTERA				
Ceratopogonidae	Biting midges		1	1
Pipunculidae	Big-headed flies		1	1
Chloropidae	Frit flies		1	4
Muscidae	Muscid flies (houseflies)	1	2	23
	Order total			29
HYMENOPTERA				
Braconidae	Braconid wasps		1	2
Mymaridae	Fairyflies		1	4
Eulophidae	Eulophid wasps	1	4	22
Encyrtidae	Encyrtid wasps	1	6	24
Eupelmidae	Eupelmid wasps		1	10
Pteromalidae	Pteromalid wasps		2	9
Eurytomidae	Seed chalcids		1	1
Formicidae	Ants		2	7
	Order total			119
Total number of invertebrates in four samples				471

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-75. Results of invertebrate sweep sampling in heavy sagebrush on the Rochelle mine area (August, 1973)

Order and Family	Common Name	Most abundant species[(a)]	Number of species groups	Total number of individuals
ARANEAE				
Araneidae	Orb weaver spiders		1	5
Thomisidae	Crab spiders		2	4
Salticidae	Jumping spiders		3	12
Unknown (spiderlings)			1	1
	Order total			22
COLLEMBOLA				
Sminthuridae	Globular springtails		1	3
	Order total			3
ORTHOPTERA				
Acrididae	Short-horned grasshoppers	1	7	31
	Order total			31
PSOCOPTERA				
Psocidae	Common barklice		1	1
	Order total			1
THYSANOPTERA				
Phlaeothripidae	Tube-tailed thrips		2	8
	Order total			8
HEMPITERA				
Miridae	Plant bugs		2	3
Lygaeidae	Seed bugs	1	1	15
Pentatomidae	Stink bugs		2	3
Unknown	—		1	1
	Order total			22
HOMOPTERA				
Cicadellidae	Leafhoppers	2	15	55
Cercopidae	Froghoppers & spittlebugs	1	2	13
Delphacidae	Delphacid planthoppers	1	3	14
Aphididae	Aphids		2	5
	Order total			87
COLEOPTERA				
Coccinellidae	Ladybird beetles		1	1
Chrysomelidae	Leaf beetles		1	2
Curculionidae	Snout beetles (weevils)		1	1
	Order total			4
LEIPIDOPTERA				
Noctuidae	Noctuid moths		1	1
Adult unknown	Moths		1	6
	Order total			7
DIPTERA				
Bombyllidae	Bee flies		2	2
Dolichopodidae	Long-legged flies		1	5
Pipunculidae	Big-headed flies		1	1
Chloropidae	Frit flies		1	1
Muscidae	Muscid flies		1	1
	Order total			10
HYMENOPTERA				
Mymaridae	Fairyflies		1	2
Eulophidae	Eulophid wasps		3	12
Encyrtidae	Encyrtid wasps		3	8
Eupelmidae	Eupelmid wasps		1	1
Pteromalidae	Pteromalid wasps		1	1
Cynipidae	Gall wasps		1	1
Formicidae	Ants	1	2	15
Unknown	—		1	4
	Order total			44
Total number of invertebrates in four samples				239

(a) Specimens representing the most abundant species have been sent to the Smithsonian Institution for positive identification.

Table A-76. Indices to invertebrate diversity and equitability at the Rochelle mine area (June and August 1973), and at the south and east plant sites (September, 1973)

	Number of species	Number of individuals	H max Highest possible diversity index	H Observed diversity index[a]	Equitability H/H max.[b]
Rochelle mine area June 1973					
scattered sagebrush	75	655	6.23	5.11	0.82
open grassland	83	2300	6.38	4.01	0.63
heavy sagebrush	97	1939	6.60	4.14	0.63
Rochelle mine area August 1973					
heavy sagebrush	70	239	6.13	5.62	0.92
open grassland	71	471	6.15	5.24	0.85
scattered sagebrush	70	378	6.13	5.04	0.82
East plant site September 1973					
ponderosa pine	40	93	5.32	4.86	0.91
cottonwood bottom	70	419	6.13	4.88	0.80
scattered sagebrush	49	343	5.61	4.22	0.75
grassland	30	366	4.91	2.12	0.43
South plant site September 1973					
abandoned field	41	192	5.36	4.58	0.86
typical sagebrush-grass mixture	45	300	5.49	3.93	0.71

(a) $H = (\log_{10} N \text{ ind}) - \frac{1}{N \text{ ind}} (\Sigma n_i \log n_i)$.

(b) Equitability is the measure of evenness of allotment of distribution of individuals among the species present.

j. Amphibians and Reptiles

Amphibians and reptiles were sampled opportunistically at each study area. Table A-77 lists possible species in addition to those actually observed. Possible species were determined from evaluations of regional species distribution records.[1,2,3]

1 Baxter, G.T. 1946. A study of the amphibians and reptiles of Wyoming. Unpublished M.S. Thesis, University of Wyoming, Laramie.

2 Conant, R. 1958. A field guide to reptiles and amphibians of the United States and Canada East of the 100th Meridian. Houghton Mifflin Co., Boston. 336 p.

3 Stebbins, R.C. 1966. A field guide to western reptiles and amphibians. Houghton Mifflin Co, Boston. 278 p.

Table A-77. Taxonomic ranking, scientific and common names for amphibians and reptiles which could be found on or near the proposed mine area and the south and east plant sites

Family Genus, species	Taxonomic Rank	Local Observed[(a)]	Records[(b)]	Possible[(c)]
	Class Amphibia — amphibians Order Anura — frogs & toads			
Pelobatidae (spadefoot toads)				
Scaphiopus bombifrons				x
(Plains spadefoot)				
Bufonidae (true toads)				
Rufo cognatus				x
(Great plains toad)				
B. woodhousei woodhousei				x
(Rocky Mountain toad)				
Hylidae (tree frogs)				
Pseudacris triseriata				x
(Chorus frog)				
Ranidae (true frogs)				
Rana pipiens		x		
(leopard frog)				
	Order Urodela — salamanders			
Ambystomidae (ambystomid salamanders)				
Ambystoma tigrinum		x		
(tiger salamander)				
	Class Reptilia — reptiles Order Chelonia — turtles & tortoises			
Testudinidae (land tortoises)				
Terrapene ornata luteola				x
(yellow box turtle)				
	Order Squamata — snakes & lizards			
Iguanidae (iguanids)				
Sceloporus undulatus garmani				x
(northern prairie lizard)				
Phrynosoma douglassi brevirostre		x		
(eastern shorthorned lizard)				
Scincidae (skinks)				
Eumeces multivirgatus				x
(many-lined skink)				
Teiidae (teiids)				
Cnemidophorus sexlineatus				x
(sixlined racerunner)				
Colubridae (colubrid snakes)				
Heterodon nasicus nasicus		x		
(plains hognose snake)				
Coluber constrictor flaviventris				
(eastern yellow bellied racer)				
Lampropeltis triangulum multistrata			x	
(pale milk snake)				
Thamnophis elegans vagrans		x		x
(wandering garter snake)				
T. sirtalis parietalis				x
(red-sided garter snake)				
T. radix				x
(plains garter snake)				
Pituophis melanoleucus		x		x
(bullsnake)				
Viperidae (true vipers)				
Crotalus viridis viridis		x		
(prairie rattlesnake)				

(a) Seen by ECI personnel.

(b) Scholarly papers; theses.

(c) Regional distribution maps.

3. Interviews

Miller, Donald. Regional Information Specialist. Wyoming Game and Fish Commission, Sheridan, Wyoming.

Wilson, Roger W. Big Game Biologist. Wyoming Game and Fish Commission, Sheridan, Wyoming.

Coy, Edward. Range Management. Thunder Basin National Grassland, U.S. Forest Service, Douglas, Wyoming.

C. NORTH PLANT SITE BIOLOGICAL INVENTORY

The purpose of the biological inventory was to provide baseline information on the existing environment of the north plant site, located in Section 32 and 33, T42N, R71W and Section 4 and 5, T41N, R71W. This inventory was divided into an aquatic report and a terrestrial report. The aquatic report placed primary emphasis on the chemical characteristics of five reservoirs, with secondary emphasis on their biological characteristics. The terrestrial report placed primary emphasis on the site's vegetation and secondary emphasis on its soils, small mammals, rabbits and hares, domestic livestock and birds. Field data for the terrestrial inventory was collected on August 13, 14, and 15, 1974. During this time a preliminary investigation of the aquatic environments was also undertaken. Collection of aquatic samples was then undertaken on August 22, 1974.

1. Aquatic Inventory

a. Methods, Materials, and Sample Locations

Water samples at the five reservoirs were collected in three separate containers for each reservoir. One container was fixed with mecuric chloride and another with nitric acid. The third container was filled with water, unfixed, so that conspicuous bubbles of oxygen would not form and promote oxidation. Once collection was completed, all bottles were flown to Denver where Accu-Labs Research, Inc. analyzed them.

Samples of living aquatic organisms were collected opportunistically at two of the five reservoirs. These reservoirs were selected because one was the site's only permanent pond and the other appeared indicative of the site's temporary ponds. Collection at these reservoirs was accomplished by sweeping small-mesh dip nets through rooted aquatics at the water's edge. Specimens were preserved in 70 percent ethyl alcohol and brought back to the laboratory for identification. Aquatic field observations augmented the net collections by categorizing those organisms not netted. Terrestrial observations augmented the investigation by identifying the dominant vegetation along the shorelines. At all reservoirs surface size and water depth were estimated whenever possible.

The aquatic sample locations are within or on the boundaries of the north plant site (figure A-11). The exact locations can be found on the U.S.G.S. map, Teckla SW, Wyoming; their coordinates are as follows:

Reservoir 1—NW corner of SW quarter of Section 4, T41N, R71W.
Reservoir 2—S boundary of SW quarter of Section 32, T42N, R71W.
Reservoir 3—W boundary of SW quarter of Section 33, T42N, R71W.
Reservoir 4—S portion of NE quarter of Section 32, T42N, R71W.
Reservoir 5—Center of NW quarter of Section 33, T42N, R71W.

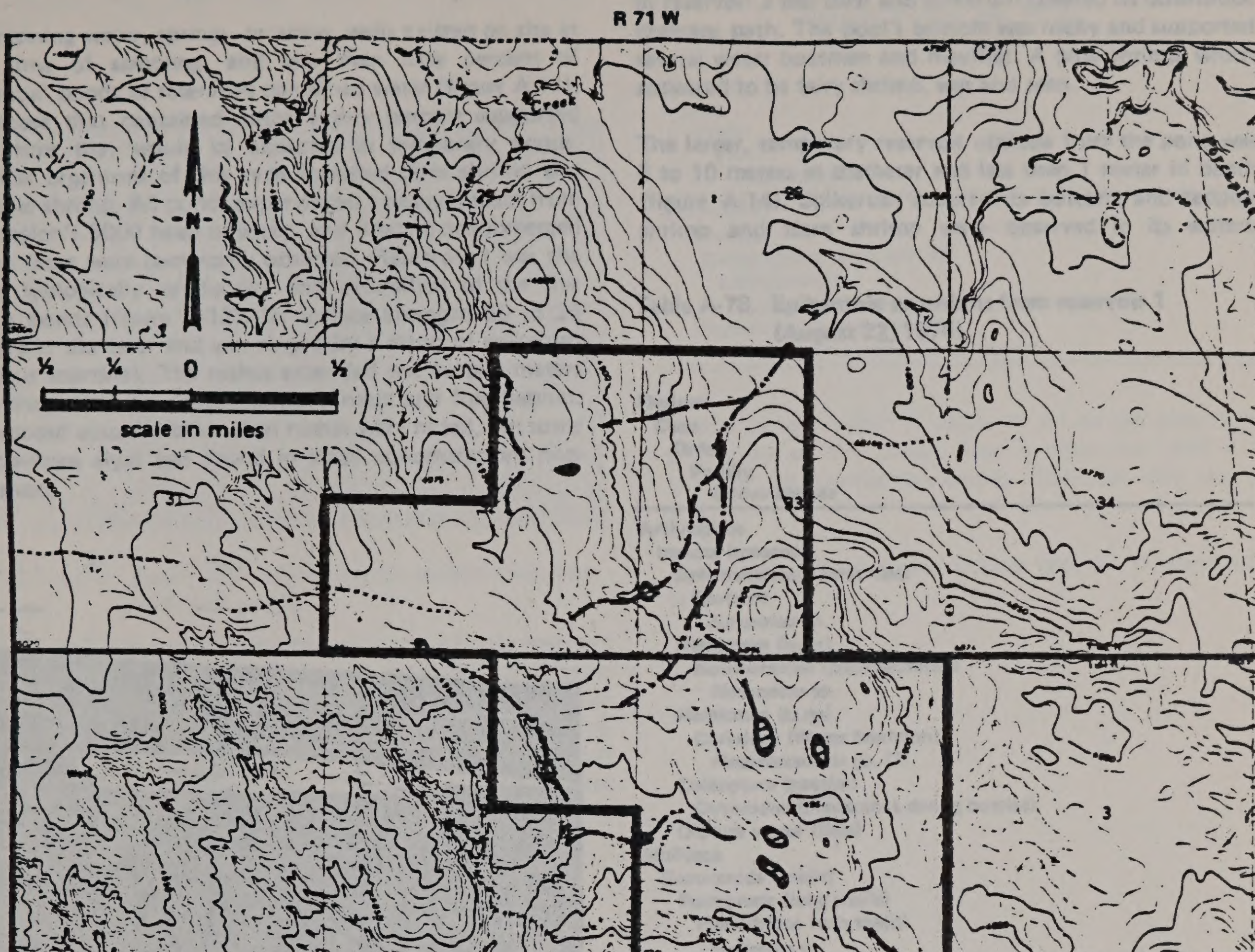

Figure A-11 Aquatic environments at the north plant site

b. Results

No running water, springs, or active wells existed on site at the time of sampling, and less than fifty percent of potential ponds or reservoirs contained water (figure A-11). Of those that contained water, eighty percent supported organisms that would be expected in temporary ponds. Typical organisms of this type included clam shrimp and tadpole shrimp. All ponds experienced a heavy impact from the region's 5000 head of sheep, and floating or submerged sheep feces were commonly observed. Reservoir 1 was the most biologically productive and diversified of the five study ponds (figure A-12). Its surface averaged 20 to 25 meters in diameter and was ringed by a stand of spikerush (*Juncus spartina*). The rushes extended one to two meters into the water, providing excellent insect and frog habitat. No rooted aquatics other than rushes were noted, but some filamentous algae was found in small concentrations near the shore.

Figure A-12 North plant site permanent reservoir 1

Adult flies from the order Odonata were seen clinging to the pond's spikerush and terrestrial spiders were seen walking on the water's surface. Adult frogs were noted to inhabit the shore zone. Members of the pond's epibenthos included mayflies, backswimmers, water boatman, predacious diving beetles, fly larvae, and orb snails (table A-78). These organisms were seen swimming through the spikerush, clinging to it, or resting on the bottom.

Samples of these organisms indicated a healthy population of Protozoans, which in this case, attached themselves to the bodies of invertebrates. Although positive identification was not made, the Protozoans appeared to be Peritrichs.

Reservoir 2 was a small pond 6 to 7 meters downslope from a larger, temporary reservoir. The water surface of the pond was 2 to 3 meters across and its depth was about 1 meter (figure A-13). The level of its water surface was about 2 meters below the level of the nearby reservoir, which suggested reservoir seepage into the pond. If such a relation does occur, then reservoir 2 is probably temporary. Water in reservoir 2 was clear and spikerush covered its downslope drainage path. The pool's bottom was rocky and supported several water boatman and mayflies. A pink shrimp, which appeared to be fairy shrimp, was also seen.

The larger, temporary reservoir upslope from the pond was 6 to 10 meters in diameter and less than 1 meter in depth (figure A-14). Spikerush covered its bottom, and tadpole shrimp and clam shrimp were observed in its waters.

Table A-78. Epibenthic organisms from reservoir 1 (August 22, 1974).

Phylum / Class / Order / Family / *Genus species*
Arthropoda
Insecta (insects)
Ephemeroptera (mayflies)
Baetidae
Amelotus sp.
Hemiptera (bugs)
Notonectidae (backswimmer)
Notonecta sp.
Hemiptera (bugs)
Corixidae (Water boatman)
Hesperocorixia sp. (?)
Coleoptera (beetles)
Dytiscidae (predacious diving beetles)
Diptera larvae (flies)
Mollusca
Gastropoda (snails)
Pulmonata (lung snails)
Planorbidae (orb snails)
Helisoma sp.

Figure A-13 North plant site small reservoir 2

Numerous frogs were noted around the reservoir's periphery.

Figure A-14 North plant site temporary reservoir upslope from reservoir 2

The least biologically productive of all ponds was reservoir 3, which was a heavily used sheep watering hole (figure A-15). The pond's surface was 12 to 15 meters across and its water was highly turbid. No vegetation ringed its shoreline, as was found in other reservoirs, and no rooted aquatics lined its bottom. The only signs of multi-cellular organisms were several partially submerged tadpoles along the shore.

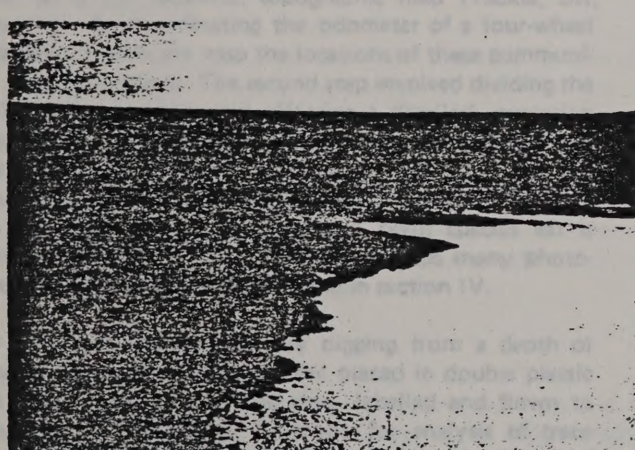

Figure A-15 North plant site temporary reservoir 3

Reservoir 4 was also frequently visited by sheep but supported more life than reservoir 3. Spikerush covered its shoreline and extended about halfway across its 8 to 12 meter diameter. When the pond was observed on August 13, tadpole shrimp and clam shrimp were observed (table A-79). By August 22 the tadpole shrimp had disappeared and only the clam shrimp remained.

Reservoir 5 was from 7 to 10 meters across and it had a muddy brown color. It appeared to be the second least productive of the ponds since it supported only a few water-striding, terrestrial insects. Spikerush also was present.

Table A-79. Epibenthic organisms from reservoir 4 (August 14 and 22, 1974).

Phylum / Class / Order / Family / *Genus species*
Arthropoda
Crustacea
Conchostraca (clam shrimp)
Leptestheriidae
Leptestheria compleximanus (Packard)
Notostraca (tadpole shrimp)
Apus longicaudatus Le Conte (?)

The results of the water sample analysis is presented in table A-80.

Table A-80. Chemical characteristics of the water in 5 reservoirs at the north plant site (August 22, 1974)

Determination, ppm	Reservoir 1	2	3	4	5
BOD, 5 Day	5	3	6	13	11
COD	24	28	33	71	61
Turbidity, (Jackson Units)	<25	<25	310	264	172
Hardness Ca, Mg, as $CaCO_3$	124	2112	189	152	42.8
Nitrate (N)	<0.1	2.9	0.28	<0.1	<0.1
Nitrite (N)	0.006	0.088	0.014	0.010	0.006
Ammonia (N)	<0.1	<0.1	0.72	0.12	0.14
Phosphorus, total	0.04	0.05	0.50	0.17	0.23
Phosphorus, ortho	0.04	<0.01	<0.01	<0.01	<0.01
Calcium	41	605	15	43	12
Magnesium	5.3	146	37	11	3.1
Potassium	6.3	8.5	4.7	10	5.5
Sodium	1.5	6.0	0.67	2.2	0.78
Alkalinity, total as $CaCo_3$	31	79	31	158	31
Sulfate	108	1848	82.4	7.1	2
Chloride	<1	2.8	<1	1.8	<1
TSS	22	9.3	228	261	250
TDS	222	2845	160	239	50
Conductivity μmhos/cm	297	2820	91	338	83
Selenium	<0.005	0.011	<0.005	<0.005	<0.005
Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	<0.1	<0.1	<0.1	<0.1	<0.1
Fluoride	0.17	0.84	0.11	0.34	0.12

2. Terrestrial Inventory

a. Methods

The vegetation was mapped in two stages. The first step involved noting the major homogeneous vegetative communities on a 7.5' U.S.G.S. topographic map (Teckla, SW, Wyoming). By coordinating the odometer of a four-wheel drive vehicle with the map the locations of these communities were ascertained. The second step involved dividing the sections into quarters and effecting a detailed vegetation map. To do this each quarter was surveyed on foot. Field notes were taken recording the major vegetative species. Where necessary samples of the vegetation were collected and identified in the laboratory. A plant species list is presented in table A-81. During both steps many photographs were taken and are presented in section IV.

Soil samples were collected by digging from a depth of about 6 inches. The samples were placed in double plastic bags which were tightly tied shut, labelled and flown to Accu-Labs in Wheatridge, Colorado for analysis of trace elements, texture, pH, nutrients (ammonia, nitrates, total nitrogen and phosphates), percent moisture and salinity.

Four soil samples were taken, one in each of the major soil types present.

Sample 1, SE¼ of SE¼ Section 4, T41N, R71W in McKenzie Clay.

Sample 2, SW¼ of SE¼ of Section 4, T41N, R71W in Ulm loam.

Sample 3, SW¼ of SW¼ of Section 32, T42N, R71W in Renohill Clay.

Table A-81. Plant species list for the north plant site (compiled in mid-August 1974)[(a)]

Scientific name	Common name
Achillea lanulosa	Yarrow
Artemesia tridentata	big sagebrush
Artemesia cana	silver sagebrush
Artemesia frigida	fringed sagebrush
Agropyron smithii	western wheatgrass
Agropyron cristatum	crested wheatgrass
Artistida longiseta	red threeawn
Astragalus spp.	milk vetch
Bouteloua grcilis	blue grama
Carex spp.	sedge
Cirsium spp.	thistle
Coryphantha vivipara	ball cactus
Distichlis stricta	salt-grass
Gutierrezia sarothrae	broom snakeweed
Juncus spp.	rush
Lupinus spp.	Lupine
Opuntia polyacantha	plains pricklypear
Oryzopsis hymenoides	Indian rice-grass
Populus sargenti	Plains cottonwood
Stipa comata	needle-and-thread
Taraxacum officinale	dandelion
Yucca glauca	soapweed

(a) This is a list of those obviously present. Those plants lacking reproductive structures because of grazing or early or very late season blooming cycles were not included.

Sample 4, SE¼ of NE¼ of Section 32, T42N, R71W in Ulm Clay Loam.

The small mammals, rabbit and hares, domestic livestock, and birds were observed opportunistically during the two periods of observation, August 13-15 and August 22, 1974.

b. Results

The results will be presented in the order indicated above, namely vegetation, soils, small mammals, rabbits and hares, birds, and domestic livestock.

The following discussion addresses those vegetation types which are mapped in figure A-16. The types to be described are sagebrush-grassland, rough-breaks, upland playas, abandoned cropland, rocky outcrops, and grassland.

1) Sagebrush-Grassland

The principal vegetation type was a sagebrush-grassland community which covered about 85 percent of the area throughout the entire north plant site. The density of sagebrush varied with slope, exposure and water availability. The sagebrush was densest in the draws of the ephemeral streams indicating that this is a plant attracted to that level of moisture. The density variations associated with slope and exposure were so variable that no conclusions could be drawn.

The grasses associated with this vegetation type were chiefly western wheatgrass and blue grama. Other grasses and forbs were present, but it was not possible to identify them because they had been heavily grazed by the flocks of sheep which were being run on this land during the survey. In addition to grasses and forbs the plains prickly pear existed in unusually dense stands in the sagebrush-grasslands community.

It is significant to note that the sagebrush-grasslands community exists chiefly on Ulm series soil. This soil is friable, up to 30 inches deep and has a moderate water percolation rate. These characteristics appeared to favor a sagebrush-grasslands community development. Some pockets of sagebrush-grassland do exist on other soils in the area, mainly Renohill series, which is shallower and exhibits a slow water percolation rate, but they are smaller both in plant height and community area.

2) Rough-Breaks

In contrast to the mine area, only a very small portion, 5 percent, of the area could be categorized as rough-breaks. The vegetation in the upper reaches of the eroded draws was snake weed (*Gutierrezia sarothrae*), soapweed (*Yucca glauca*), Indian rice-grass (*Oryzopis hymenoides*), and scattered patches of lupine (*Lupinus* spp.) and a few unidentified grasses.

The vegetation of the lower reaches of the draws was characterized chiefly by western wheatgrass, side-oat grama, thistles (*Cirsium* spp.), dandelions (*Taraxacum officinale*), yarrow (*Achillea lanulosa*) and rushes (*Junus* spp., probably *arcticus*). These steep walled lower reaches were located on the north plant site only in the SW¼ of the NE¼ of Section 5, T41N, R71W.

3) Upland Playas

Upland playa basins comprised 5 to 8 percent of the total area of the north plant site. The vegetation in these playas was mainly western wheatgrass and sedges. The most striking feature of these playas was their sharp vegetation boundary where sagebrush and plains prickly pear disappear and sedges and grasses become the dominant vegetation.

4) Abandoned Cropland

Investigation of the plant site indicated that in one area, comprising 5 to 10 percent of the total, there existed an abandoned cropland located in the eastern half of Section 4, T41N, R71W. Such land usually contains few, if any, shrubs and cactus, and although this abandoned cropland generally followed this pattern, there were some sagebrush and cactus invasions on the margins. The present vegetation was characterized chiefly by western wheatgrass, blue grama, crested wheatgrass and assorted forbs. Of particular interest within this area was a single plains cottonwood tree (*Populus sargenti*), which was also the only tree on the entire site.

The fact that this parcel was indeed formerly cropland is substantiated by organized vegetation patterns noted in aerial photographs of the area taken in May, 1970 and the present remains of an abandoned homestead.

With the knowledge of the combined factors of: (1) an abandoned homestead, (2) the amount of invasion of the native sagebrush and plains pricklypear, and (3) the severe periods of drought during the 1930s, it was assumed that this abandoned cropland has been unused for 30 to 40 years.

5) Rocky Outcrops

These were located on high points on the site. They were very small measuring no more than 50 feet in diameter. The soils were thin to nonexistant. The chief vegetation was soapweed, plains pricklypear, various cushion plants and a few isolated clumps of grasses.

6) Grassland

The grassland community comprised less than 5 percent of the total area of the north plant site. The grasses were chiefly western wheatgrass and blue grama.with occasional invasions of needle-and-thread and Indian rice-grass. Plains pricklypear was also evident at the same density as was seen in the sagebrush-grassland community.

The results of the soil analysis by Accu-Labs was presented in table A-82 and table A-83. The soils of the north plant site are quite uniform, all being characteristic of upland grazing regions. As can be seen in figure IV-2 the soils are are mostly Ulm series loam and clay loam (Ua and Uc). It is only in the rough broken land in Section 5 T41N R71W

b. Results

The results will be presented in the order indicated above, namely vegetation, soils, small mammals, rabbits and hares, birds, and domestic livestock.

The following discussion addresses those vegetation types which are mapped in figure A-15. The types to be described are sagebrush-grassland, rough-breaks, upland draws, abandoned cropland, rocky outcrops, and grassland.

1) Sagebrush-Grassland

The principal vegetation type was a sagebrush-grassland community which covered about 85 percent of the area throughout the entire north plant site. The density of sagebrush varied with slope, exposure and water availability. The sagebrush was densest in the draws of the ephemeral streams indicating that this is a plant responding to that level of moisture. The density variations associated with slope and exposure were so variable that no conclusions could be drawn.

The grasses associated with this vegetation type were chiefly western wheatgrass and blue grama. Other grasses and forbs were present, but it was not possible to identify them because they had been heavily grazed by the flocks of sheep which were being run on this land during the survey. In addition to grasses and forbs the plains pricklypear existed in unusually dense stands in the sagebrush-grasslands community.

It is significant to note that the sagebrush-grasslands community exists chiefly on Ulm series soil. This soil is friable, up to 30 inches deep and has a moderate water percolation rate. These characteristics are suitable to large sagebrush-grasslands community establishment. Some pockets of sagebrush-grassland do exist on other soils in the area, mainly Renohill series, which is shallower and exhibits a slow water percolation rate, but they are smaller both in plant height and community area.

2) Rough-Breaks

In contrast to the mine area, only a very small portion, 5 percent, of the area could be categorized as rough-breaks. The vegetation in the upper reaches of the wooded draws was snake weed (*Gutierrezia sarothrae*), soapweed (*Yucca glauca*), Indian rice-grass (*Oryzopsis hymenoides*), and scattered patches of lupine (*Lupinus* spp.) and a few unidentified grasses.

The vegetation of the lower reaches of the draws was characterized chiefly by western wheatgrass, side-oats grama, thistles (*Cirsium* spp.), dandelions (*Taraxacum officinale*), yarrow (*Achillea lanulosa*) and rushes (*Juncus* spp., probably *arcticus*). These steep walled lower reaches were located on the north plant site only in the SW¼ of the NE¼ of Section 5, T41N, R71W.

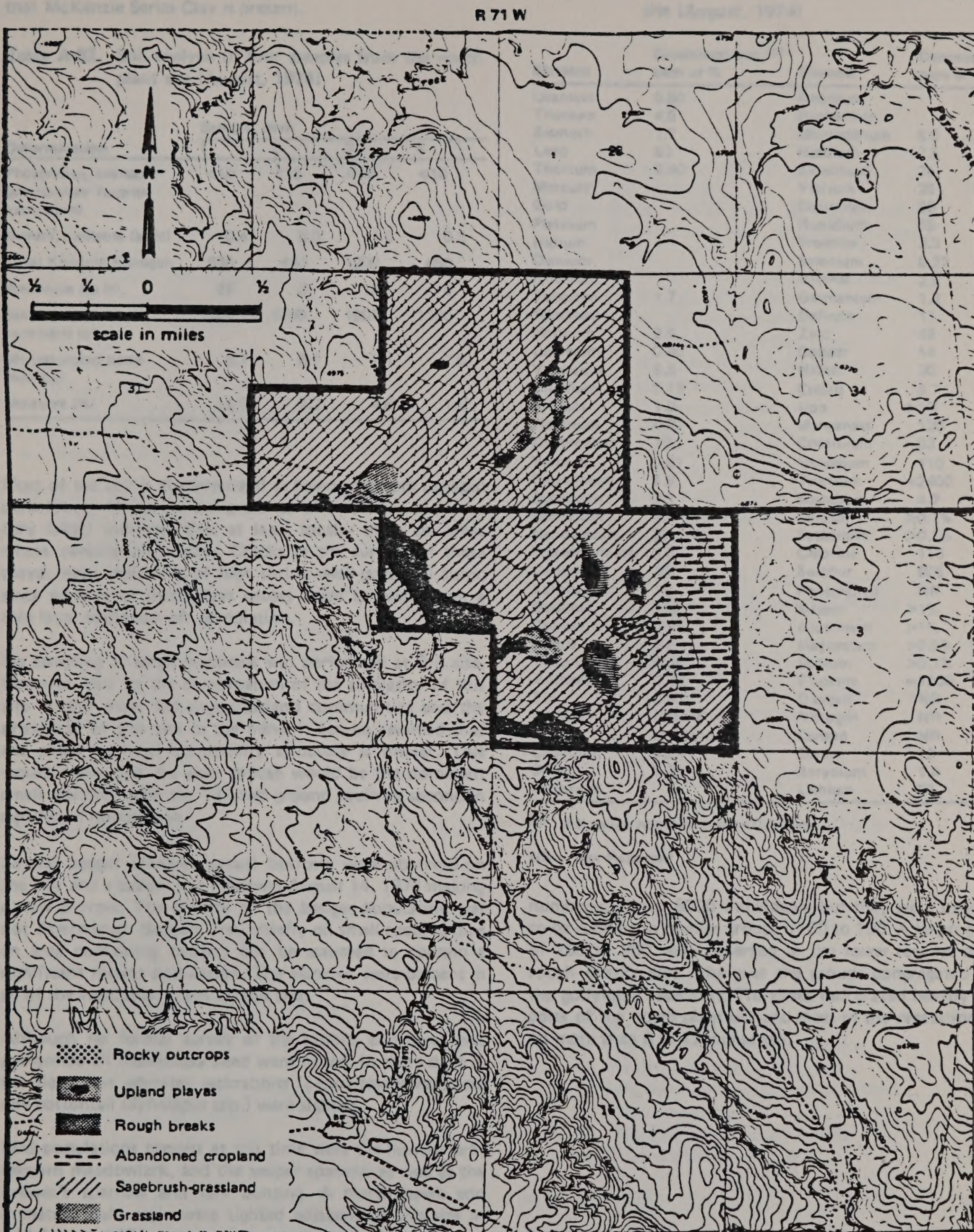

Figure A-16 Vegetation types of north plant site

that Renohill series appears and only in the upland playas that McKenzie Series Clay is present.

Table A-82. Soil analysis of four samples from the north plant site (August, 1974)

Determination	Sample, ppm 1	2	3	4
Phosphorus, available (ammonium fluoride extraction)	<10	<10	<10	<10
Nitrate, available (as N)	0.4	0.3	1.6	0.5
Total Kjeldahl Nitrogen	830	440	1300	450
Ammonia (as N)	26	9	16	9
Salinity (expressed as soluble salts)	1300	1100	1800	1100
pH (saturated paste method)	6.7	8.1	7.1	7.5
Moisutre (%)	15.0	7.2	4.6	1.6

Most of the soil is characterized as having medium to rapid percolation. However, the presence of a number of playas (dry lakes) indicates that at least locally these are areas where percolation is slow. Cracks in the surface of these playas were indicative of high shrink-swell-potential clays; since wetting of these clays causes them to swell, even a thin layer could seal off percolation.

No sampling of small mammals was performed at this site. However, due to the combination of the similarity of this site to the mine site sage-grassland communities and the proximity of this site to the mine, it can be assumed that the small mammal community structure is similar. This would mean that the deer mouse would be the dominant small mammal with the 13-lined ground squirrels second in significant importance.

Several badger (*Taxidea taxus*) burrows were observed on the site and a badger was observed August 14, 1974 making a new burrow. The density of the badger population was not determined. Badgers prey chiefly on small rodents thus an area containing badgers can be assumed to contain a significant rodent population. The burrows were present in all of the vegetation types on this site.

Although no formal survey of the rabbits and hares was performed all individuals sited were noted. In three days in the field, five whitetail jackrabbits (*Lepus townsendi*) and one cottontail (*Sylvilagus* spp.) were sighted.

Bird populations present at this time were the horned lark, western meadowlark, and the vesper sparrow as well as the Brewer's sparrow and lark bunting. A marsh hawk and immature bald eagle were sighted adjacent to this site in mid-August, 1974.

Domestic sheep were being grazed on this site at the time of the observations in mid-August 1974. The entire population numbered about 5000 individuals but they were observed to be running in smaller groups of 50 to 100. A larger group of 100 to 200 were observed in the lower reaches of the rough breaks area otherwise the groups congregated near the gully-plug reservoirs. The sheep had grazed heavily in all parts of the north plant site and most of the vegetation was no more than 6 to 12 inches tall.

Table A-83. Soil trace element analysis for north plant site (August, 1974)

Element	Concentrations,[a] ppm or %	Element	Concentrations,[a] ppm or %
Uranium	0.50	Rhodium	
Thorium	4.5	Ruthenium	
Bismuth	1.7	Molybdenum	8.0
Lead	53	Niobium	7.5
Thallium	0.40	Zirconium	25
Mercury		Yttrium	25
Gold		Strontium	86
Platinum		Rubidium	59
Iridium		Bromine	3.3
Osmium		Selenium	0.27
Rhenium		Arsenic	2.9
Tungsten	1.7	Germanium	1.3
Tantalum		Gallium	11
Hafnium	2.5	Zinc	46
Lutecium	0.45	Copper	14
Ytterbium	5.5	Nickel	30
Thullium	0.15	Cobalt	8.7
Erbium	1.0	Iron	>1%
Holmium	0.91	Manganese	120
Dysprosium	10	Chromium	33
Terbium	0.61	Vanadium	110
Gadolinium	5.9	Titanium	≈2400
Europium	2.1	Scandium	4.7
Samarium	4.9	Calcium	>0.1%
Neodymium	38	Potassium	>0.1%
Praseodymium	4.6	Chlorine	110
Cerium	43	Sulphur	605
Lanthanum	10	Phosphorus	NR
Barium	210	Silicon	>1%
Cesium	0.86	Aluminum	>1%
Iodine	6.9	Magnesium	>0.5%
Tellurium	0.05	Sodium	>0.1%
Antimony	0.30	Fluorine	≈1000
Tin	0.81	Oxygen	NR
Indium	internal standard	Nitrogen	NR
		Carbon	NR
Cadmium	0.24	Boron	10
Silver	0.35	Beryllium	1.4
Palladium		Lithium	27

(a) All values not shown are <0.1 ppm

NR – Not Reported

APPENDIX C-2. PLANT SITE STUDIES,

ATMOSPHERIC DATA

LIST OF FIGURES

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LIST OF TABLES

A. METEOROLOGICAL AND CLIMATOLOGICAL PARAMETERS — AIR POLLUTION FACTORS

Interrelated processes between topographic features and meteorological conditions dictate the transport and diffusion of atmospheric emissions. These factors plus the configuration and characteristics of emission sources ultimately govern an atmospheric impact. This subsection discusses the important meteorological parameters related to this project.

1. Data Sources

Current climatological, meteorological and air quality data within the study region are limited. This section provides a summary of the available data and figure B-1 depicts the locations where data was gathered.

Climatological sources are drawn from Casper, Douglas, Moorcroft, Gillette and Sheridan. These data provide surface values of temperature, relative humidity, precipitation, wind speed, and wind direction. The only sources with wind records are: (1) the Casper station, (2) the Moorcroft station (providing 30 months of surface wind data from January, 1950 to July, 1952) and (3) the Sheridan station. In the region of interest, no upper air observations of wind or thermal structures exist.

A mechanical weather station, which was established June, 1973, in Section 7, Township 41N, Range 69W, Campbell County, provides the only site specific meteorological data for the Rochelle mine. Data consists of surface temperature, relative humidity, precipitation, wind speed and wind direction.

Upper air temperature soundings were conducted by Dr. Marwitz and his associates from the University of Wyoming.[1] These studies consisted of PIBAL's being launched 12 miles east of Reno Junction between January 14 and 18 of 1974. These data provide short-term but extremely useful information on both wind and thermal structures.

The PIBAL studies used standard fixed free-lift meteorological balloons and single theodolite tracking techniques. Launches occurred during daylight hours with no particular schedule, although greatest effort focused on morning (0800-1100 MST) and late afternoon (1400-1700 MST). Vertical temperature soundings acquired concurrently with each PIBAL launch were obtained from radio-controlled drone aircraft, which flew ascending spiral patterns over the site.

A similar but more intensive study was conducted by a research team from Metronics Associates, Inc. from December 2 to 7, 1973.[2] In this study PIBAL's were released at Mud Flats, a region approximately 24 miles north-northeast of Douglas. Launches occurred hourly between 0700 and 1800 MST, followed by nocturnal releases at 2200, 2400 and 0400 MST. Vertical temperature soundings were acquired from an instrumented aircraft flying ascending and/or descending spiral patterns at five fixed locations along a north-south axis at both Mud Flats and the Rochelle mine. These flights were conducted during early morning and late afternoon to capture the important extremes and transition periods. This short acquisition time is not sufficient to characterize information as typical or atypical; however, the results provided important data that was previously nonexistent.

A wind speed and direction set installed and maintained by the State of Wyoming Department of Environmental Quality provides surface wind data for Reno Junction.

A fully instrumented meteorological station which includes a 150-foot tower, (established December, 1973 in Section 31, Township 35N, Range 70W, Converse County) provides relatively comprehensive data in the area of the south plant

1 Marwitz, John D. University of Wyoming Department of Atmospheric Resources.

2 Nunes, Robert A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Technical Report no. 192, January.

in the region of interest, no upper air observations of winds or thermal structure exist.

Anaconda's weather station, which was established June, 1973, in Section 7, Township 41N, Range 69W, Campbell County, Wyoming, has only site specific meteorological data for the Rochelle mine. Data consists of surface temperature, relative humidity, precipitation, wind speed and wind direction.

Upper air temperature soundings were conducted by Dr. Marwitz and his associates from the University of Wyoming.[1] These studies consisted of PIBAL's using theodolite [illegible] made east of Bond Junction between January 14 and 18 of 1974. These data provide short-term but extremely useful information on both winds and thermal structure.

The PIBAL studies used standard fixed theodolite meteorological balloons and single theodolite tracking techniques. Launches occurred during daylight hours with no particular schedule, although greatest effort focused on morning (0800-1100 MST) and late afternoon (1400-1700 MST). Vertical temperature soundings acquired concurrently with each PIBAL launch were obtained from radio-controlled drone aircraft, which flew ascending spiral patterns over the site.

A similar, but more intensive study was conducted by a research team from Meteorology Research, Inc. from December 2 to 7, 1973.[2] In this study PIBAL's were released at Mud Flats, a region approximately 25 miles north-northwest of Douglas. Launches occurred hourly between 0700 and 1800 MST, followed by nocturnal release at 2200, 2400 and 0400 MST. Vertical temperature soundings were acquired from an instrumented aircraft flying ascending and/or descending spiral patterns at two fixed locations along a north-south axis at both Mud Flats and the Rochelle mine. These flights were conducted during early morning and late afternoon to capture the important extremes and transition periods. This short sampling time is not sufficient to characterize information on typical or seasonal patterns, but results produced important data that was previously unavailable.

A wind speed and direction sensor installed and maintained by the State of Wyoming Department of Environmental Quality provides surface wind data for the [illegible] location.

A fully instrumented meteorological station which includes a 150-foot tower, installed September, 1973 in Section 31, Township 33N, Range 72W, Converse County, provides continuous meteorological data in the area of the proposed plant.

1. Marwitz, John D. University of Wyoming, Department of Atmospheric Resources.
2. Nickola, Robert A. 1974. Air investigation of meteorological dispersion for Douglas, Wyoming. Meteorology Research Report No. 150, January.

A. METEOROLOGICAL AND CLIMATOLOGICAL PARAMETERS — AIR POLLUTION FACTORS

Interrelated processes between topographic features and meteorological conditions dictate the transport and diffusion of atmospheric emissions. These factors plus the configuration and characteristics of emission sources ultimately govern air atmospheric impact. This subsection discusses the important meteorological parameters related to this project.

1. Data Sources

Current climatological, meteorological and air quality data within the study region are limited. This section provides a summary of the available data and figure B-1 depicts the locations where data was gathered.

Climatological sources are drawn from Casper, Douglas, Moorcroft, Gillette, etc. stations. These data provide surface values of temperature, relative humidity, precipitation, wind speed, and wind direction. The only sources with wind records are: (1) the Casper station, (2) the Moorcroft station (consisting 22 months of surface wind data from January, 1950 to July, 1952) and (3) the Sheridan station.

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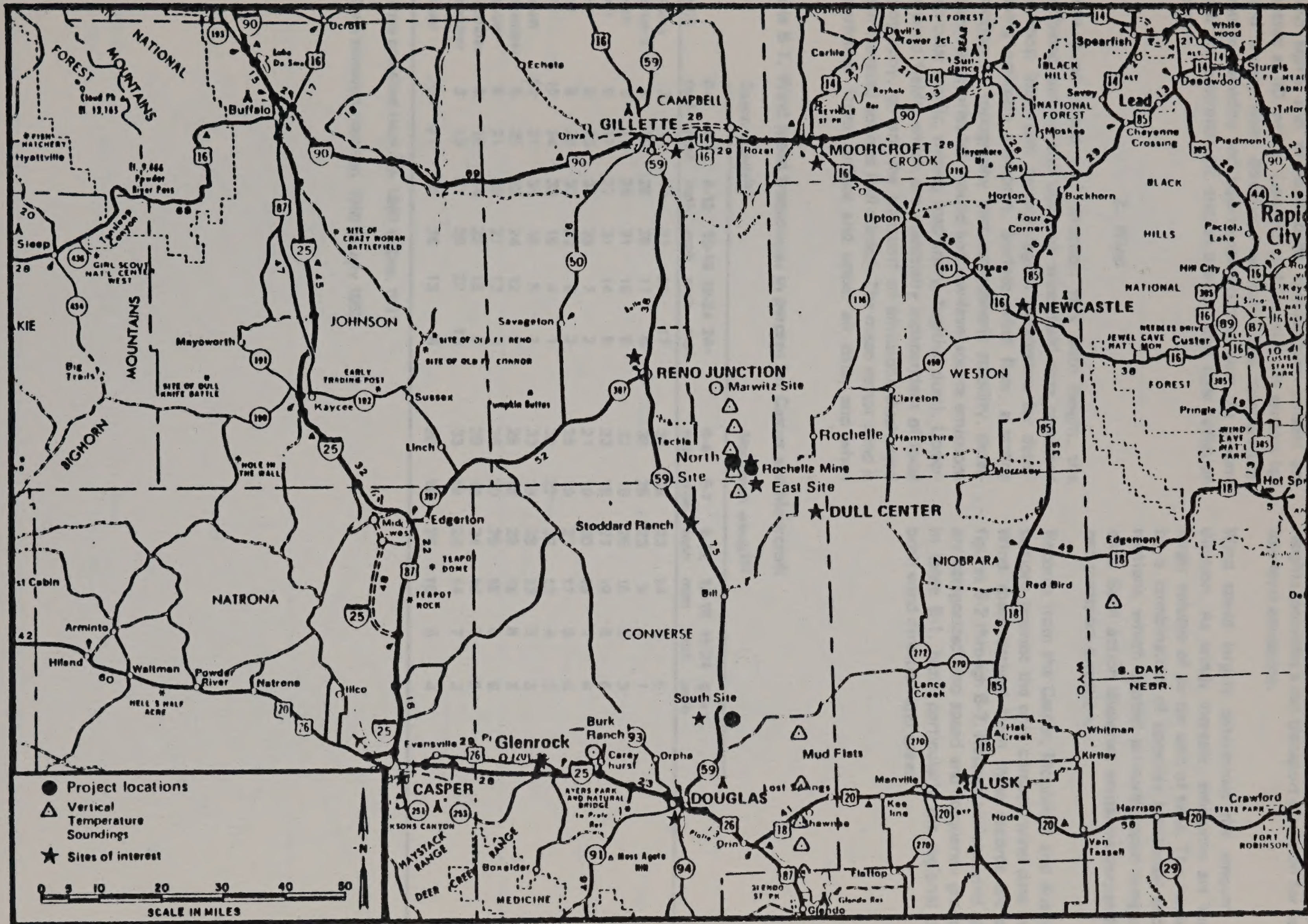

Figure B-1 Locations of meteorological and air quality sampling sites

site. On the 150-foot tower, wind speed, wind direction, wind sigma and one-half delta temperature sensors are located at 40 meters. Located at 10 meters are sensors for wind speed, wind direction, one-half delta temperature, relative humidity and base temperature sensors. At ground level are precipitation, station pressure and solar radiation sensors.

2. Wind

Since wind speed and direction vary with height, the combined surface and upper-air wind field data represent the most important meteorological parameters for determining emission transport. Surface wind flow, a strong function of topography and atmospheric stability, determines trajectories for ground and low-level source emissions (vehicular traffic, mining machinery, fugitive dust). Upper-air wind fields, which are essentially independent of local topography, govern the transport of emissions discharged from elevated sources (tall stacks). The mean vector wind is determined from surface and upper air data, and when averaged through the layers to estimated effective source heights, provides a net transport direction for both high and low level emissions.

Wind speed largely determines the amount of emission dilution. As winds increase, emissions are mixed with a larger volume of air per unit of time. This mixing is assisted by a combination of complex horizontal and vertical air motions, which depend primarily upon temperature gradients. Such action disperses emissions perpendicular to the net transport direction.

Records from the Casper, Moorcroft and Sheridan weather stations provide the only climatic wind data in the region. Wind roses derived from these records are presented in figures B-2 through B-7. Related surface wind speeds, which are categorized into speed and frequency groups, are listed in table B-1. Note particularly the regional difference in both wind direction and speed.

Table B-1. Wind speed frequencies in percent for Casper and Moorcroft

	Casper winds[a]						Moorcroft winds[b]					
Month	0-4 mph	5-7 mph	8-12 mph	13-18 mph	19-24 mph	24+ mph	0-4 mph	5-7 mph	8-12 mph	13-18 mph	19-24 mph	24+ mph
January	3	13	17	27	23	17	36	18	23	14	4	5
February	4	15	28	28	17	6	38	25	23	9	4	1
March	3	16	26	31	16	8	32	19	25	15	5	3
April	5	17	27	31	14	5	23	18	27	19	8	6
May	6	23	34	28	7	2	21	19	30	19	7	4
June	8	28	33	23	6	2	25	19	27	17	9	4
July	10	34	33	19	4	1	32	22	27	13	4	3
August	10	31	34	18	5	1	33	19	28	13	5	3
September	6	25	32	24	12	2	25	18	29	18	8	3
October	5	21	30	27	13	4	26	20	25	18	6	6
November	6	18	24	28	18	8	29	19	24	16	7	5
December	3	13	21	29	22	13	33	19	23	14	7	3
Annual	6	21	28	26	13	6	29	19	26	15	6	4

(a) Data compiled from Jan. 1967 to Dec. 1971.

(b) Data compiled from Jan. 1950 to July 1952.

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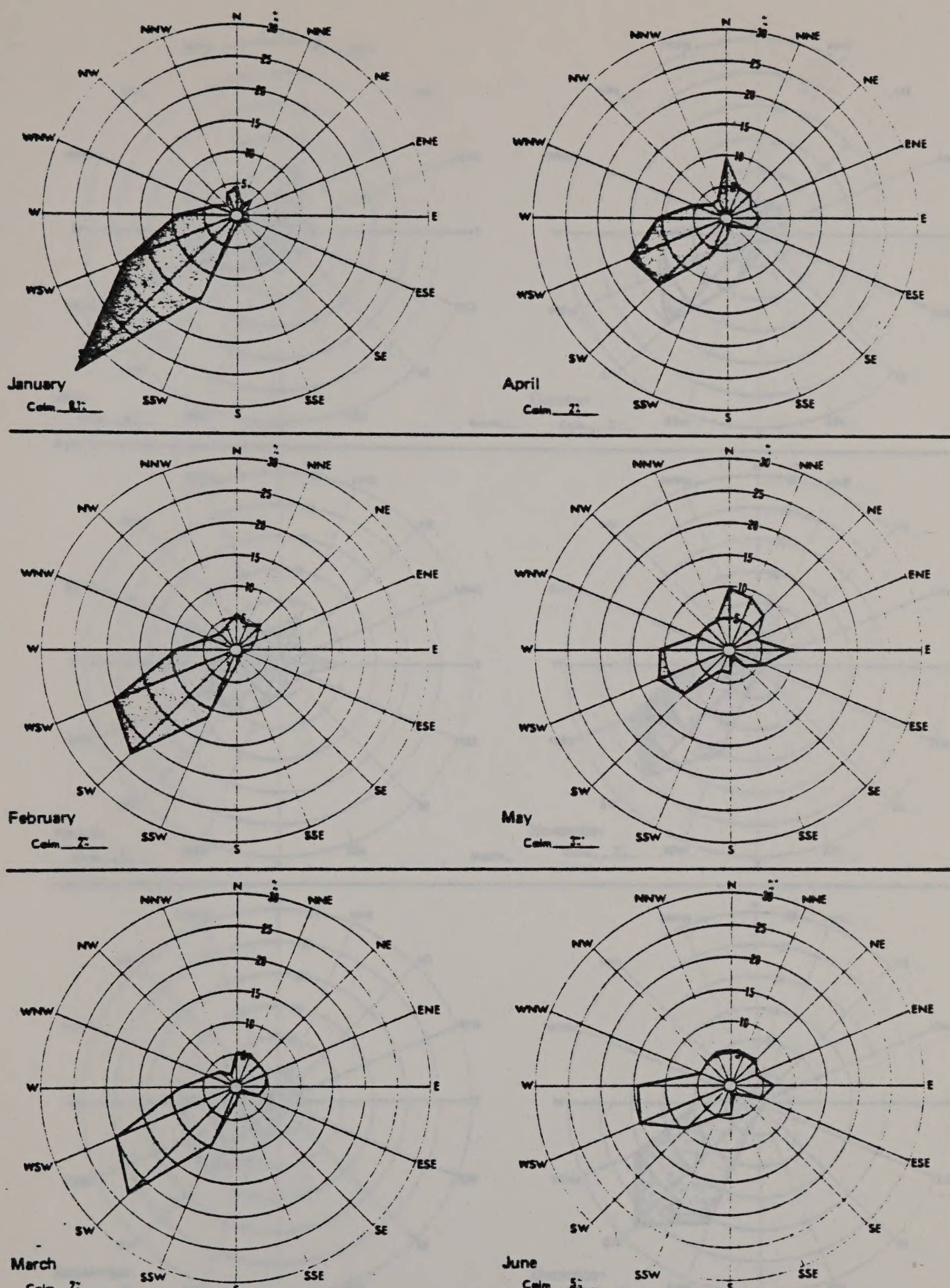
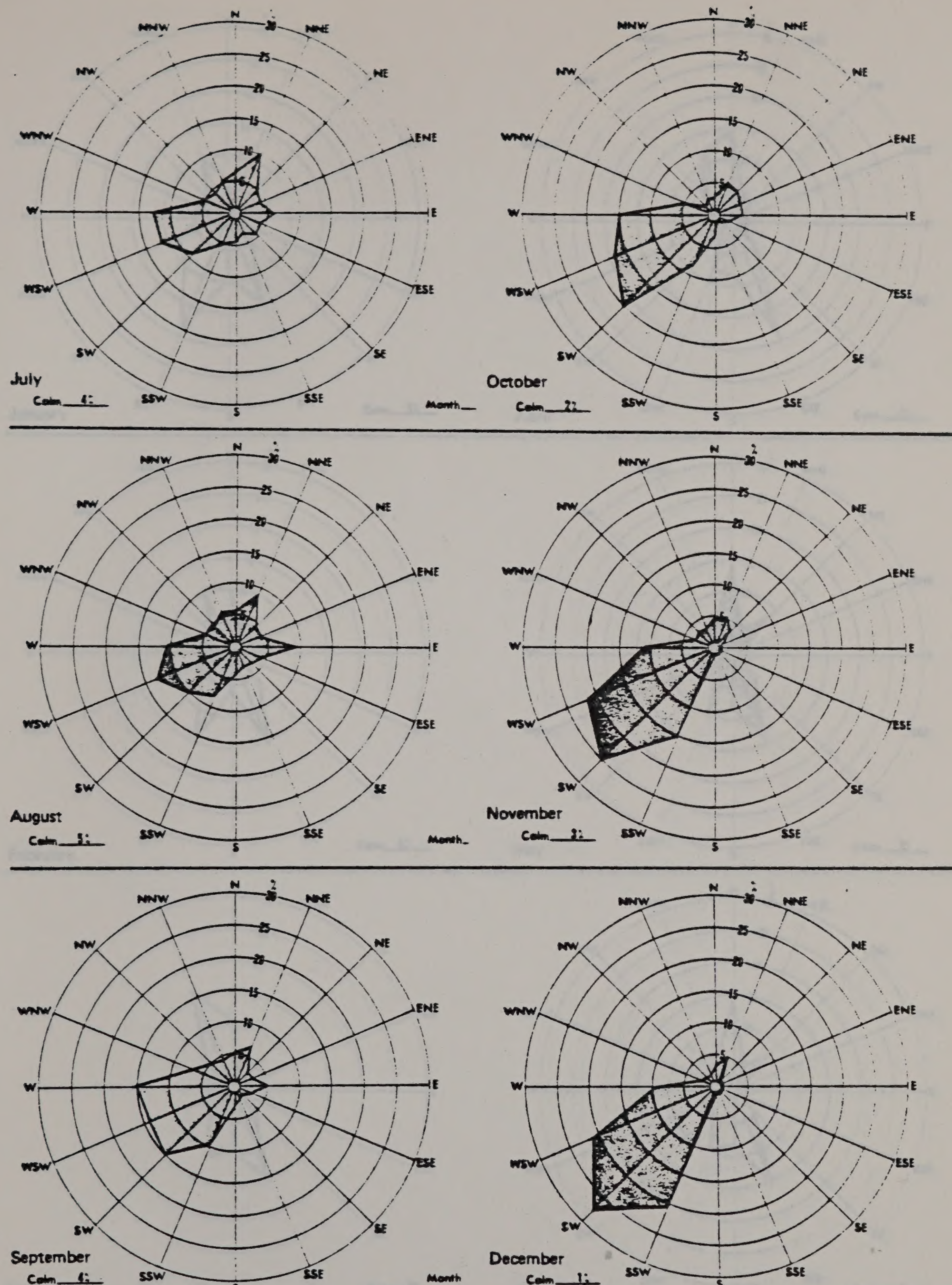


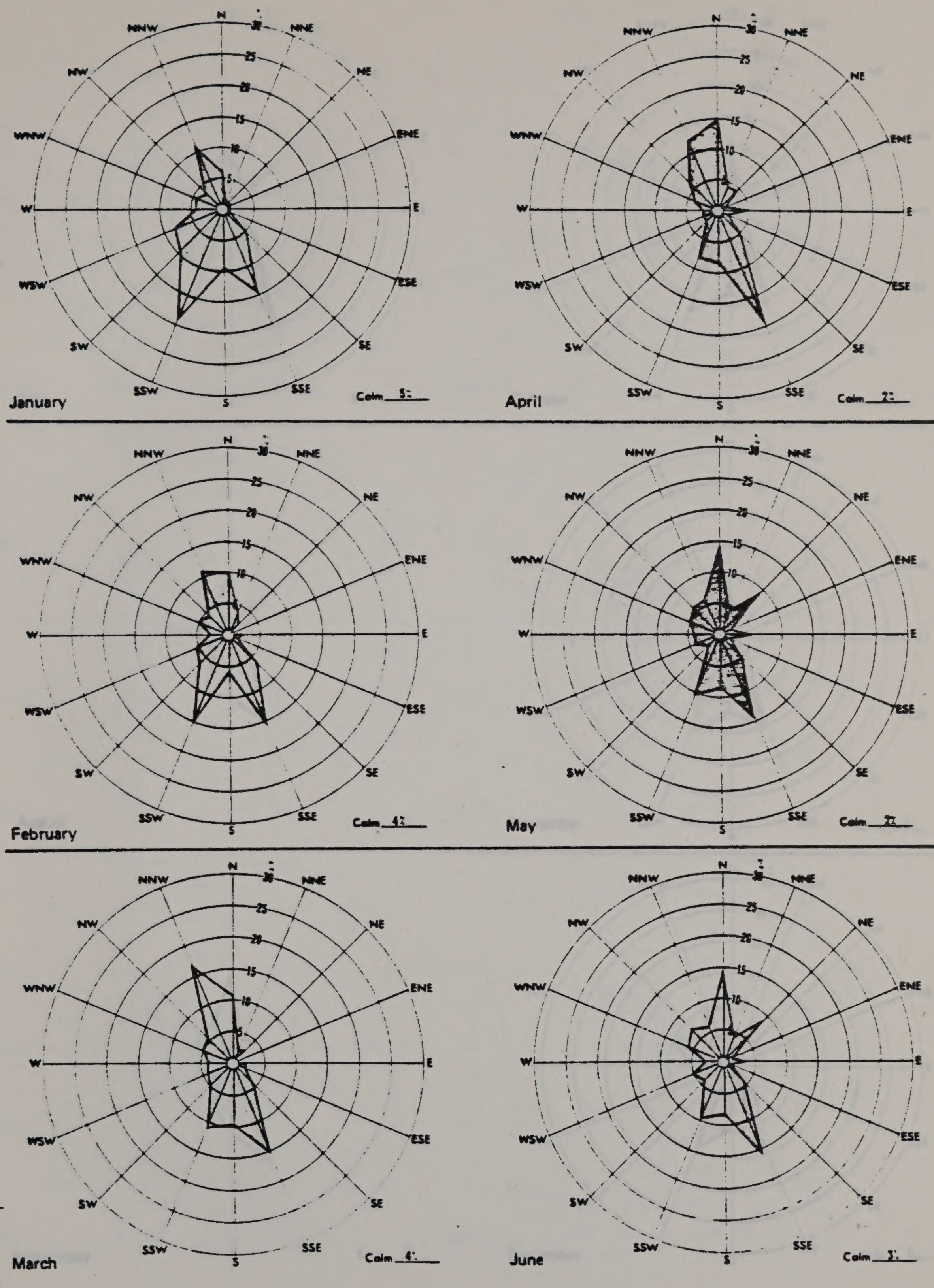
Note: Direction shown from which the wind is blowing. Data compiled from Jan. 1967 to Dec. 1971. Eight observations per day.

Figure B-2 Casper wind roses (January-June)



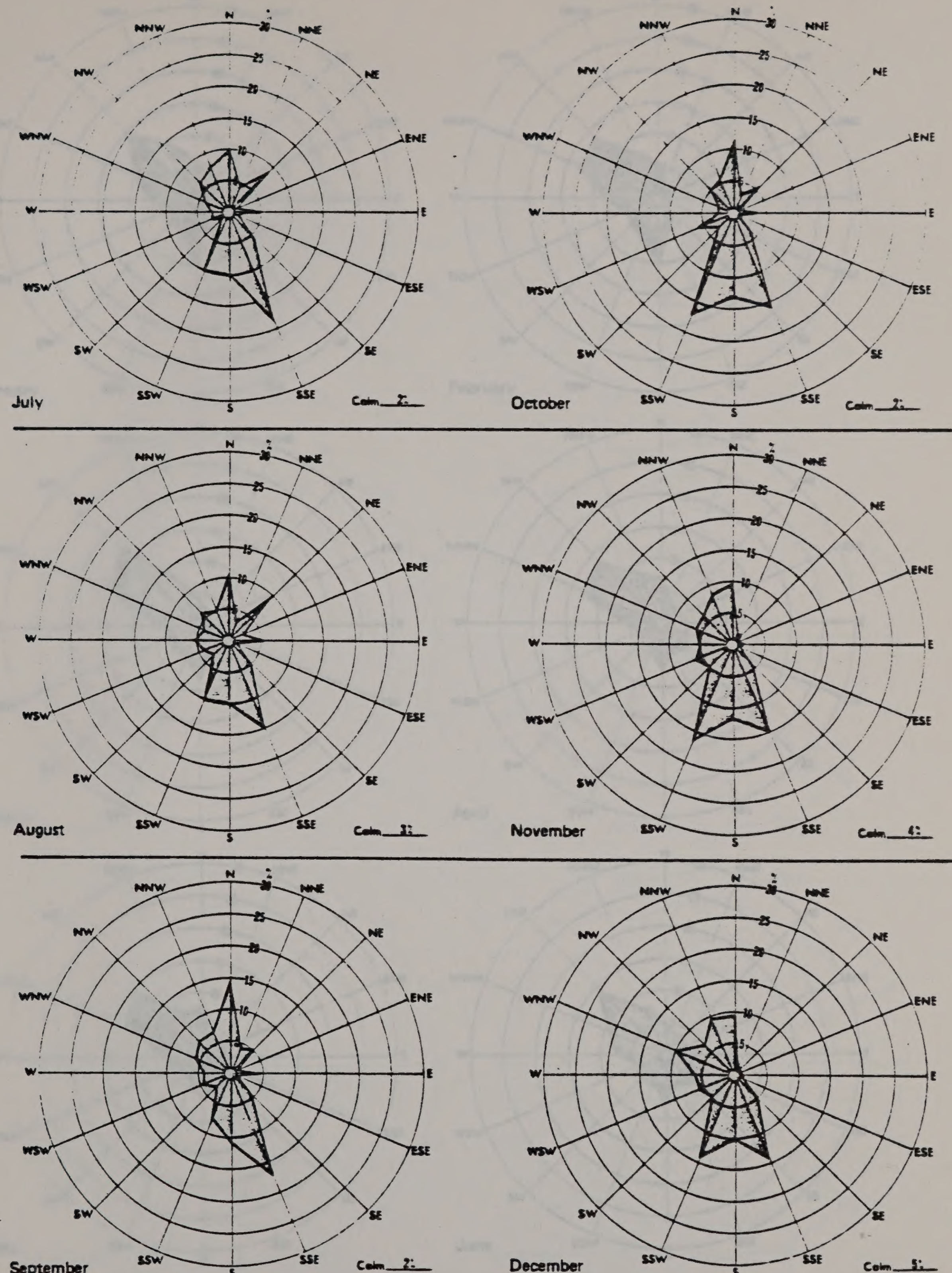
Note: Direction from which the wind is blowing. Data compiled from Jan. 1967 to Dec. 1971. Eight observations per day.

Figure B-3 Casper wind roses (July-December)



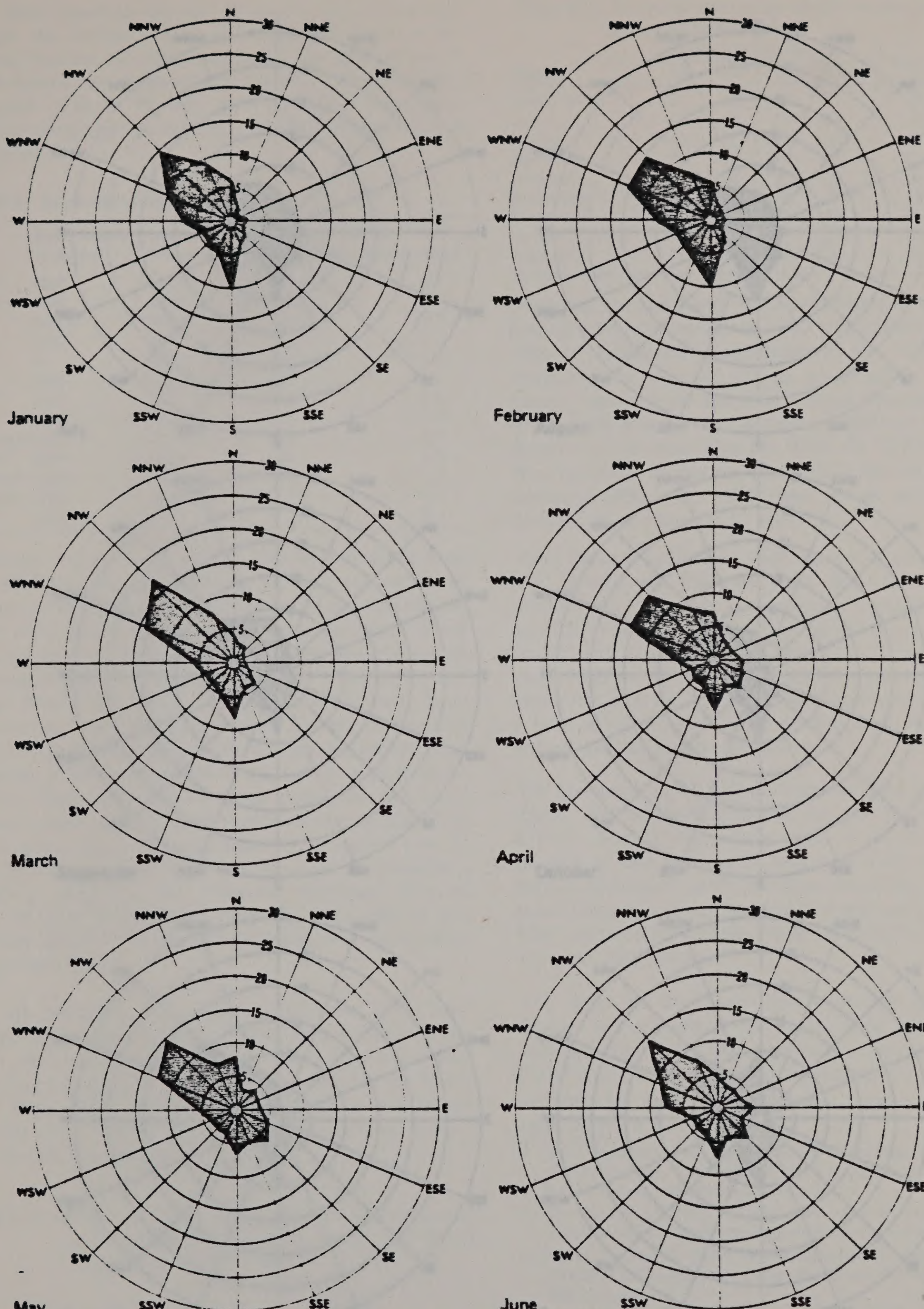
Note: Direction from which the wind is blowing. Data compiled from Jan. 1950 to July 1952. Twenty-four observations per day (hourly).

Figure B-4 Moorcroft wind roses (January-June)



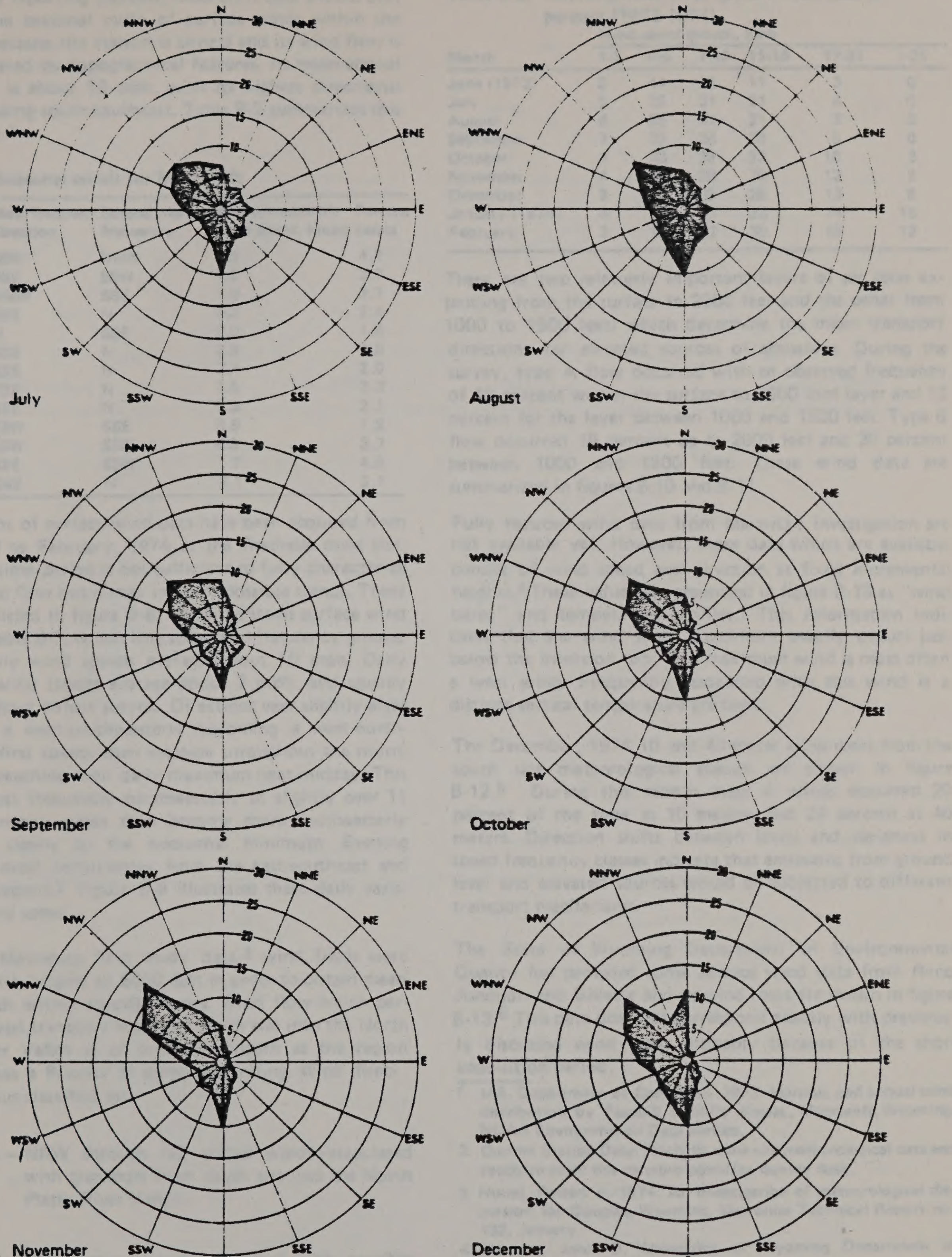
Note: Direction from which the wind is blowing. Data compiled from Jan. 1950 to July 1952. Twenty-four observations per day (hourly).

Figure B-5 Moorcroft wind roses (July-December)



Note: Direction from which the wind is blowing. From U.S. Weather Bureau data compiled June 1953 to May 1957.

Figure B-6 Sheridan wind roses (January-June)



Note: Direction from which wind is blowing. From U.S. Weather Bureau data compiled June 1953 to May 1957.

Figure B-7 Sheridan wind roses (July-December)

Of the three reporting stations, Moorcroft data should best represent the seasonal cycle of surface winds within the mine area because the station is closest and its wind flow is least dominated by topographical features. Its mean annual wind speed is about 10 mph, with its highest directional frequency being south-southeast. Table B-2 summarizes this information.[1]

Table B-2. Seasonal winds for Moorcroft

Month	Most frequent direction	Second highest frequency	Average monthly wind speed, knots	Percent calms
January	SSW	NNW	7.5	4.7
February	SSE	SSW	6.2	3.7
March	NNW	SSE	7.6	3.7
April	SSE	N	9.2	2.4
May	N	SSE	9.0	1.9
June	SSE	N	8.8	2.8
July	SSE	N	7.4	2.0
August	SSE	N	7.5	3.3
September	SSE	N	8.5	2.1
October	SSW	SSE	8.9	1.8
November	SSW	SSE	8.5	3.7
December	SSE	SSW	7.7	4.9
Annual	SSE	N	8.1	3.1

Nine months of surface wind data have been acquired from June, 1973 to February, 1974 at the Rochelle mine site. This short time period is not sufficient to fully characterize typical wind flow but it may indicate possible trends. These trends are listed in figure B-8, which contains surface wind roses and table B-3, which lists speed and frequency groups. Typical daily wind speeds average about 10 mph. Daily minimum wind speeds average about 7 mph, and usually occur one hour before sunrise. Directions veer slightly after this, with a west-southwesterly becoming a west-northwesterly. Wind speeds then increase throughout the morning hours, reaching their daily maximum near midday. This wind is most frequently northwesterly at slightly over 11 mph. Afternoon winds then become more southeasterly decreasing slowly to the nocturnal minimum. Evening winds are most consistently from the east-southeast and southeast sectors.[2] Figure B-9 illustrates these daily variations in wind speed.

From the Metronics field study data,[3] wind fields were averaged with heights to 5000 feet in order to obtain mean vector winds within specific layers. Wind flow which permits potential transport from the south site into the North Platte River Valley is of primary concern as the region currently has a Priority II particulate rating. Wind directions are thus classified as:

Type A — NNW through NE vector winds—associated with transport from south site into the North Platte River Valley.

Type B — NW vector winds—associated with possible transport into the Valley.

Type C — All other directions—associated with no transport into the valley.

Table B-3. Rochelle mine wind speed frequencies in percent (1973-1974)

Month	Wind speed groups, mph 1-3	4-6	7-10	11-16	17-21	>21
June (1973)	8	44	33	11	3	0
July	5	35	31	21	4	0
August	6	35	31	21	3	0
September	7	32	28	28	5	0
October	4	33	28	22	10	3
November	4	18	28	30	12	8
December	3	18	29	28	13	8
January (1974)	4	22	21	23	14	16
February	3	15	22	30	18	12

There are two relatively important layers of air (one extending from the surface to 2000 feet and the other from 1000 to 1500 feet) which determine the mean transport directions for elevated sources of emissions. During the survey, type A flow occurred with an observed frequency of 19 percent within the surface to 2000 foot layer and 12 percent for the layer between 1000 and 1500 feet. Type B flow occurred 19 percent up to 2000 feet and 39 percent between 1000 and 1500 feet. These wind data are summarized in figures B-10 and B-11.

Fully reduced wind data from Marwitz's investigation are not available yet. However, those data which are available consist of wind speed and direction at fixed incremental heights.[4] These values are presented in figure B-19 as "wind barbs" and temperature profiles.) This information indicates that the wind speed maximum usually occurs just below the inversion top. This maximum wind is most often a west wind. Frequently associated with this wind is a distinct vertical temperature gradient.

The December, 1974 10 and 40-meter wind roses from the south site meteorological station are shown in figure B-12.[5] During this month type A winds occurred 20 percent of the time at 10 meters, and 29 percent at 40 meters. Direction shifts between levels and variances in speed frequency classes indicate that emissions from ground level and elevated sources would be subjected to different transport mechanisms.

The State of Wyoming Department of Environmental Quality has provided some surface wind data from Reno Junction and Gillette and its wind roses are shown in figure B-13.[6] This data does not correspond exactly with previously discussed wind data, probably because of the short acquisition period.

1 U.S. Department of Commerce. 1973. Monthly and annual wind distribution by Pasquill stability classes, Moorcroft, Wyoming. NOAA Environmental Data Service.

2 Current Station Data. Rochelle mine site meteorological data and southern plant site meteorological/air quality data.

3 Nunes, Robert A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Technical Report no. 192, January.

4 Marwitz, John D. University of Wyoming Department of Atmospheric Resources.

5 Current Station Data. Rochelle mine site meteorological data and southern plant site meteorological/air quality.

6 Department of Environmental Quality. Correspondence. State of Wyoming.

Of the three reporting stations, Medicine Bow should best represent the seasonal cycle of surface winds within the mine area because the station is closer and its wind flow is least dominated by topographical features. Its mean annual wind speed is about 10 mph, with its highest directional frequency being south-southeast. Table B-2 summarizes this information.[1]

Table B-2. Seasonal winds for Medicine Bow

Month	Most frequent direction	Second frequent direction	Average wind speed, mph	[illegible]
January	SSW	NNW	7.5	8.7
February	SSE	SSW	8.2	[illegible]
March	NNW	SSE	7.0	[illegible]
April	SSE	N	8.2	[illegible]
May	N	SSE	9.0	1.8
June	SSE	N	8.5	2.8
July	SSE	N	[illegible]	[illegible]
August	SSE	N	7.8	3.2
September	SSE	N	8.0	2.1
October	SSW	SSE	8.9	1.0
November	SSW	SSE	[illegible]	[illegible]
December	SSE	SSW	7.7	4.9
Annual	SSE	N	8.1	[illegible]

Nine months of surface wind data have been acquired from June, 1973 to February, 1974 at the Rochelle mine site. This short time period is not sufficient to fully characterize typical wind flow but it may indicate possible trends. These trends are listed in figure B-8, which contains monthly wind roses and table B-3, which lists speed and frequency details. Typical daily wind speeds average about 10 mph. Daily minimum wind speeds average about 7 mph, and usually occur one hour before sunrise. Directions are mostly westerly, with a west-southwesterly frequency, a west-northwesterly. Wind speeds then increase throughout the morning hours, reaching their daily maximum near midday. This wind is most frequently northwesterly at slightly over 11 mph. Afternoon winds then become more southeasterly, decreasing slowly to the nocturnal minimum. Evening winds are most consistently from the east-southeast and southeast sectors.[2] Figure B-9 illustrates these daily variations in wind speed.

From the Metronics field study data[3] wind fields were averaged with heights to 5000 feet in order to obtain mean vector winds within specific layers. Wind flow which permits potential transport from the south site into the North Platte River Valley is of primary concern as this region currently has a Priority II particulate rating. Wind directions are thus classified as:

Type A — NNW through NE vector winds—associated with transport from south site into the North Platte River Valley.

Type B — NW vector winds—associated with possible transport into the Valley.

Type C — All other directions—associated with no transport into the valley.

Table B-3. Monthly wind speed frequencies in percent (1973-1974)

Month	1-3	4-7	8-12	13-18	19-24	>24
	Wind speed classes, mph					
June, 1973	8	46	33	11	2	0
July	13	36	31	21	8	0
August	6	33	37	21	4	0
September	7	32	29	26	6	0
October	4	25	29	30	10	2
November	4	13	34	29	12	8
December	4	18	30	28	11	9
January, 1974	8	22	21	23	14	13
February	2	13	25	34	18	12

There are two relatively important levels of air flow extending from the surface to 2000 feet and the other from 1000 to 1500 feet which determine the main transport directions for possible sources of emissions. During the study, Type A flow occurred with an apparent frequency of 16 percent within the surface to 2000 foot level and 12 percent for the level between 1000 and 1500 feet. Type B flow occurred 15 percent up to 2000 feet and 20 percent between 1000 and 1500 feet. These wind data are summarized in figures B-10 and B-11.

Fairly reliable wind data from the Medicine Bow area are not available yet. However, these data which are available consist of wind speed and direction at three meteorological heights. These can be summarized in figure B-12 as "wind barbs" and radiosonde profiles. This information indicates that the wind speed maximum usually occurs just below the inversion top. This maximum wind is most often a west wind. Frequently associated with this wind is a distinct vertical temperature gradient.

The December, 1974 10 and 40 meter wind roses from the south site meteorological station are shown in figure B-13. During this period, type A winds occurred 30 percent of the time at 10 meters, and 20 percent at 40 meters. Direction shifts between levels and variations in sizes from wind roses indicate that emissions from ground level and elevated sources would be subjected to different transport mechanisms.

The State of Wyoming Department of Environmental Quality has provided some surface wind data from Rock Junction and Medicine Bow and its wind roses are shown in figure B-14.[6] This data does not correspond exactly with previously reported wind data, probably because of the short collection period.

1. U.S. Department of Commerce, 1973, Monthly and seasonal distributions, Hanna, Medicine Bow, and Muddy Gap, Wyoming: Asheville, N.C., Environmental Data Service.

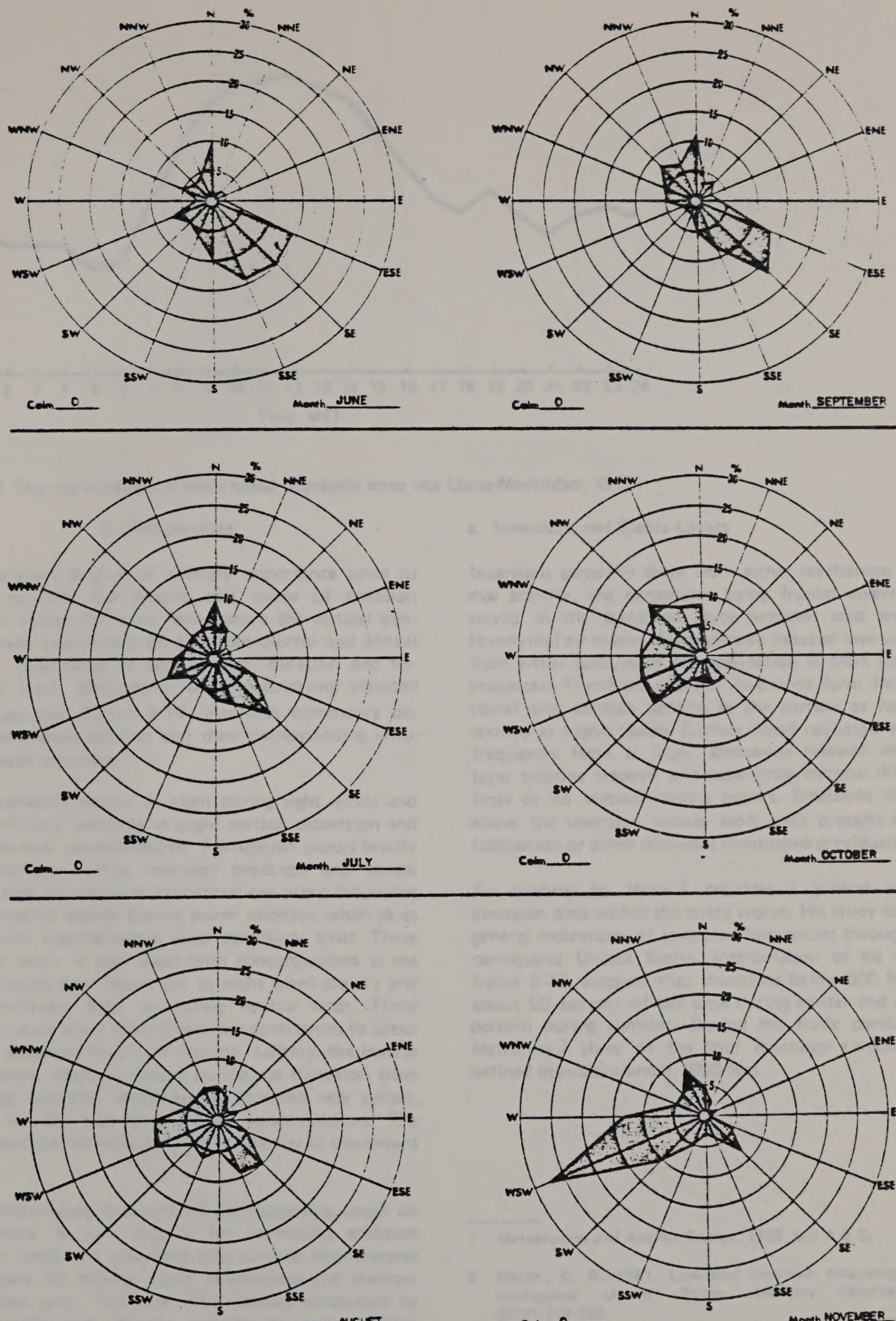
2. Environmental Data Service, Rochelle mine site meteorological data and surface weather observations, various data.

3. Metronics Associates, 1974, An investigation of meteorological conditions for Rochelle Wyoming: Metronics Technical Report No. 192, Palo Alto, Calif.

4. [illegible], John D., University of Wyoming Department of Atmospheric Sciences.

5. Dames and Moore, 1974, Rochelle mine site meteorological data and additional surface meteorological data.

6. Department of Environmental Quality, Cheyenne, Wyoming, State of Wyoming.



Note: Direction from which wind is blowing.

Figure B-8 Rochelle mine wind roses (June-November, 1973)

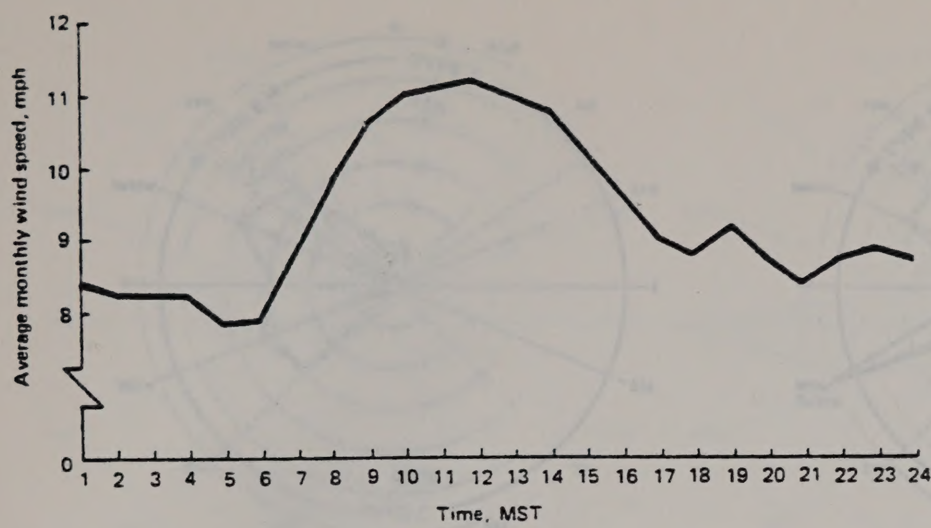


Figure B-9 Diurnal variation in wind speed, Rochelle mine site (June-November, 1973)

3. Temperature

Air temperature data is of primary importance since its structure governs the extent and mode of emission dispersion. Within the lower atmosphere the vertical thermal structure experiences considerable diurnal and annual variations. Classifying its type, extent, duration and frequency is vital, particularly when considering elevated emission sources. Figure B-14 illustrates commonly observed temperature profiles and their corresponding influence on stack emissions.[1]

Fanning typically occurs at night during light winds and stable conditions, resulting in slight vertical dispersion and low ground-level concentrations. Fumigation occurs briefly in the morning during inversion breakups and causes relatively high ground-level concentrations along the plume length. Looping occurs during warm middays when skies are clear and superadiabatic lapse conditions exist. These conditions result in high short-term concentrations at the surface. Coning may occur day or night when cloudy and windy conditions exist or during neutral lapse. These conditions cause lower ground-level concentrations to occur at greater distances than with looping. Lofting, the inverse of fumigation, typically occurs during the transition from unstable to inversion conditions as observed near sunset, resulting in very low ground-level concentrations. The inversion surface provides an effective barrier to downward mixing.

Surface temperature data without corresponding upper air measurements is not helpful for estimating emission dispersion. Upper air soundings plus surface temperatures are necessary for mixing depth calculations and environmental lapse rates. The brief field studies conducted by both Metronics and Marwitz provide the only available information on upper air thermal structures and are discussed below. Figure B-1 indicates the location of these studies.

a. Inversions and Stable Layers

Inversions generally form from either mechanical or thermal activity, the exceptions being frontal inversions observed in the transition layer between cold and warm (overlying) air masses. Mechanically induced inversions arise from either turbulence and convection or from subsidence processes. Thermally induced inversions form from radiational and contact cooling at the surface or radiational cooling at higher levels. Surface based radiation inversions frequently form at night. Emissions released within the layer become trapped and experience minimal dilution, as little or no vertical mixing occurs. Emissions discharged above the inversion remain aloft until brought down by fumigation or other processes mentioned previously.

An analysis by Hosler[2] provides a general source of inversion data within the study region. His study establishes general indications of inversion frequencies throughout the contiguous United States. Interpolation of his isograms, figure B-15, suggests that inversions below 500 feet occur about 50 percent of the time during winter and about 33 percent during summer. During the study conducted by Metronics,[3] three of the four mornings exhibited well-defined inversions under 1000 feet.

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1 Meteorology and Atomic Energy, 1968. U.S.A.E.C.

2 Hosler, C. R. 1961. Low-level inversion frequency in the contiguous United States. Monthly Weather Rev. 89(9):319-339.

3 Nunes, Robert A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Technical Report no. 192. January.

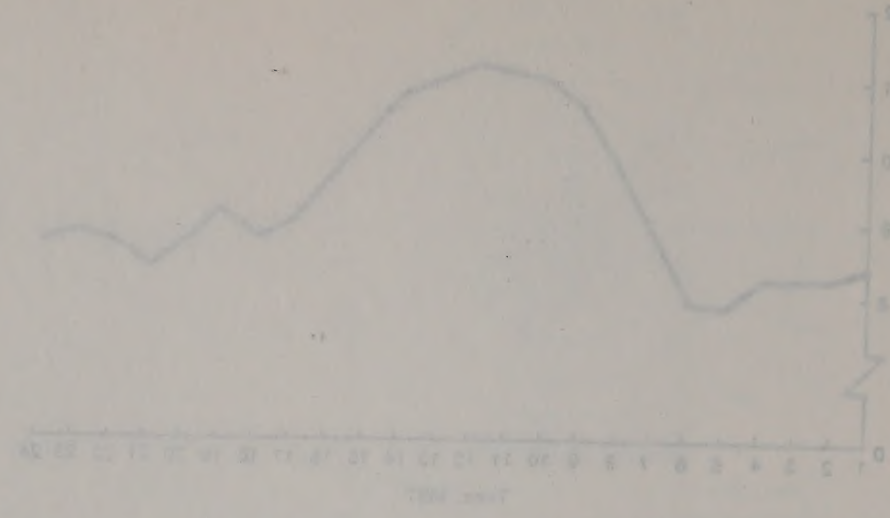


Figure B-9. Diurnal variation in wind speed, Rawlins area [illegible] 1982)

3. Temperature

Air temperature data is of primary importance since its structure governs the extent and mode of emission dispersion. Within the lower atmosphere the vertical thermal structure experiences considerable diurnal and annual variations. Classifying its type, extent, duration and frequency is vital, particularly when considering elevated emission sources. Figure B-14 illustrates commonly observed temperature profiles and their corresponding influence on stack emissions.[1]

Fanning typically occurs at night during light winds and stable conditions, resulting in slight vertical dispersion and low ground-level concentrations. Fumigation occurs briefly in the morning during inversion breakups and causes relatively high ground-level concentrations along the plume length. Looping occurs during warm months when skies are clear and superadiabatic lapse conditions exist. These conditions result in high short-term concentrations at the surface. Coning may occur day or night when cloudy, and windy conditions exist or during neutral lapse. These conditions cause lower ground-level concentrations to occur at greater distances than with looping. Lofting, the inverse of fumigation, typically occurs during the transition from unstable to inversion conditions in observed near sunset, resulting in very low ground-level concentrations. The inversion surface provides an effective barrier to downward mixing.

Surface temperature data without corresponding upper air measurements is not helpful for estimating emission dispersion. Upper air soundings plus surface temperatures are necessary for mixing depth calculations and environmental lapse rates. The brief field studies conducted by both Mecombs and Marwitz provide the only available information on upper air thermal structures and are discussed below. Figure B-1 indicates the location of these studies.

4. Inversions and Stable Layers

[illegible]

[illegible]

1. [illegible]

2. [illegible]

3. [illegible]

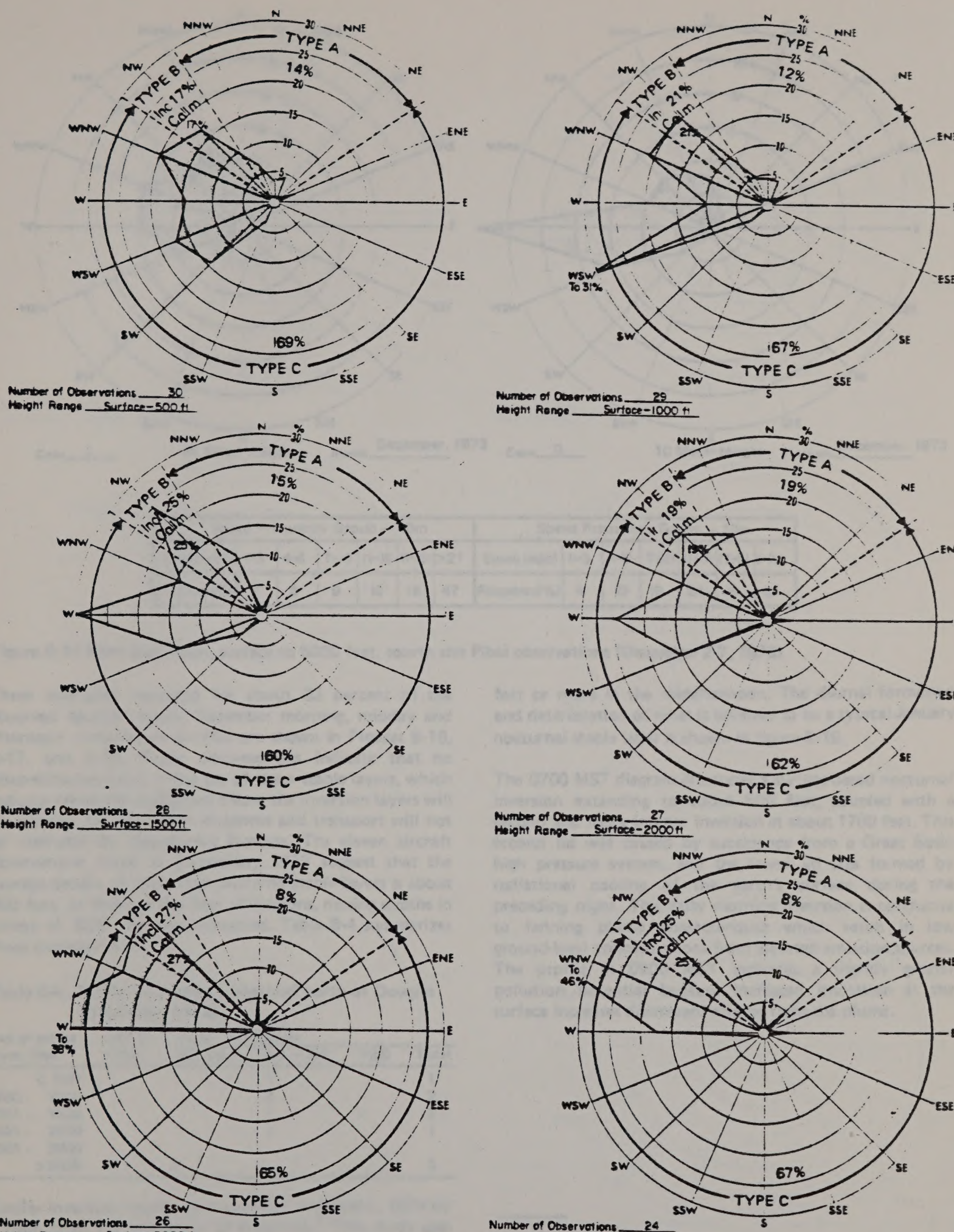
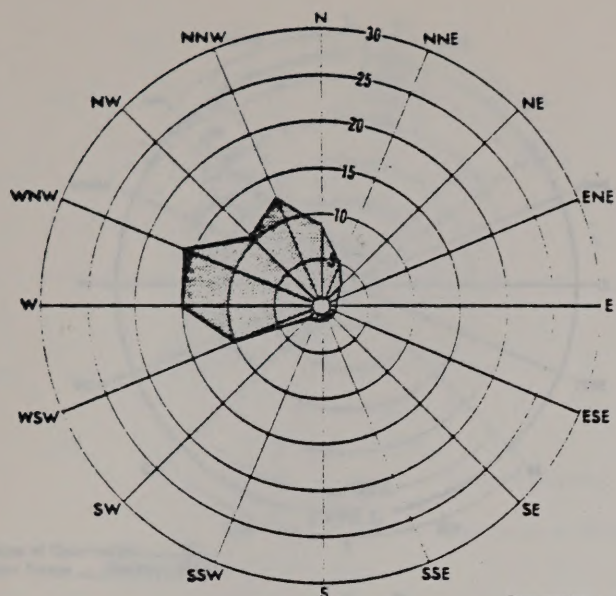
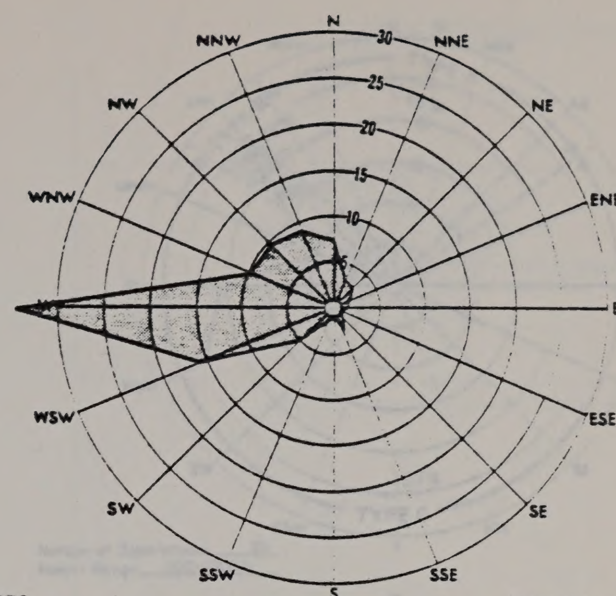


Figure B-10 Vector mean wind roses, south site Pibal observations (December 2-7, 1973)



Calm 1 40 Meter Height Month December, 1973



Calm 0 10 Meter Height Month December, 1973

Speed Frequency Group – 40m							Speed Frequency Group – 10m						
Speed (mph)	1-3	4-6	7-10	11-16	17-21	>21	Speed (mph)	1-3	4-6	7-10	11-16	17-21	>21
Frequency(%)	2	5	9	18	18	47	Frequency(%)	4	10	19	24	19	22

Figure B-11 Wind aloft roses, surface to 5000 feet, sourth site Pibal observations (December 2-7, 1973)

These inversions persisted for about 33 percent of the observed daylight hours. December morning, midday and afternoon temperature profiles are shown in Figures B-16, B-17, and B-18. These cross-sections indicate that no discontinuities exist in the tip of these stable layers, which indicate emissions discharged below the inversion layers will be trapped for significant distances and transport will not be restricted by topographic features. The eleven aircraft observations made in December, 1973 suggest that the average depths of the winter morning stable layers is about 900 feet. In three of the four afternoons, mixing depths in excess of 3000 feet were observed. Table B-4 summarizes these characteristics.

Table B-4. Stable layer depths observed north of Douglas (December, 1973).

Top of stable layer, feet	$\Delta T(^\circ C) = T_{top} - T_{bottom}$ <-3.0	-3.0 – 0	0.1 – 3.0	>3.0	Total
< 800			1		1
800 - 1000			2		2
1001 - 1500			1	1	2
1501 - 2000			1		1
2001 - 3000					
>3000	1	2			3

Similar inversion results were observed in January, 1974 by a team from the University of Wyoming.[1] This study suggests that a semipermanent lid exists over the study area at about 1200 feet during the morning, rising to over 3000 feet or more in the midafternoon. The diurnal formation and deterioration of what is believed to be a typical January nocturnal stable layer is shown in figure B-19.

The 0700 MST diagram illustrates a surface-based nocturnal inversion extending to about 500 feet, coupled with a second and more intense inversion at about 1700 feet. This second lid was caused by subsidence from a Great Basin high pressure system, and the lower lid was formed by radiational cooling of the earth's surface during the preceding night. This early morning inversion is conducive to fanning plume characteristics which result in low ground-level concentrations from elevated emission sources. The profile at 0900 MST indicates a slightly greater pollution potential because increased insolation at the surface increases downward mixing from the plume.

1 Marwitz, John D. 1974. University of Wyoming. Department of Atmospheric Resources.

C-100

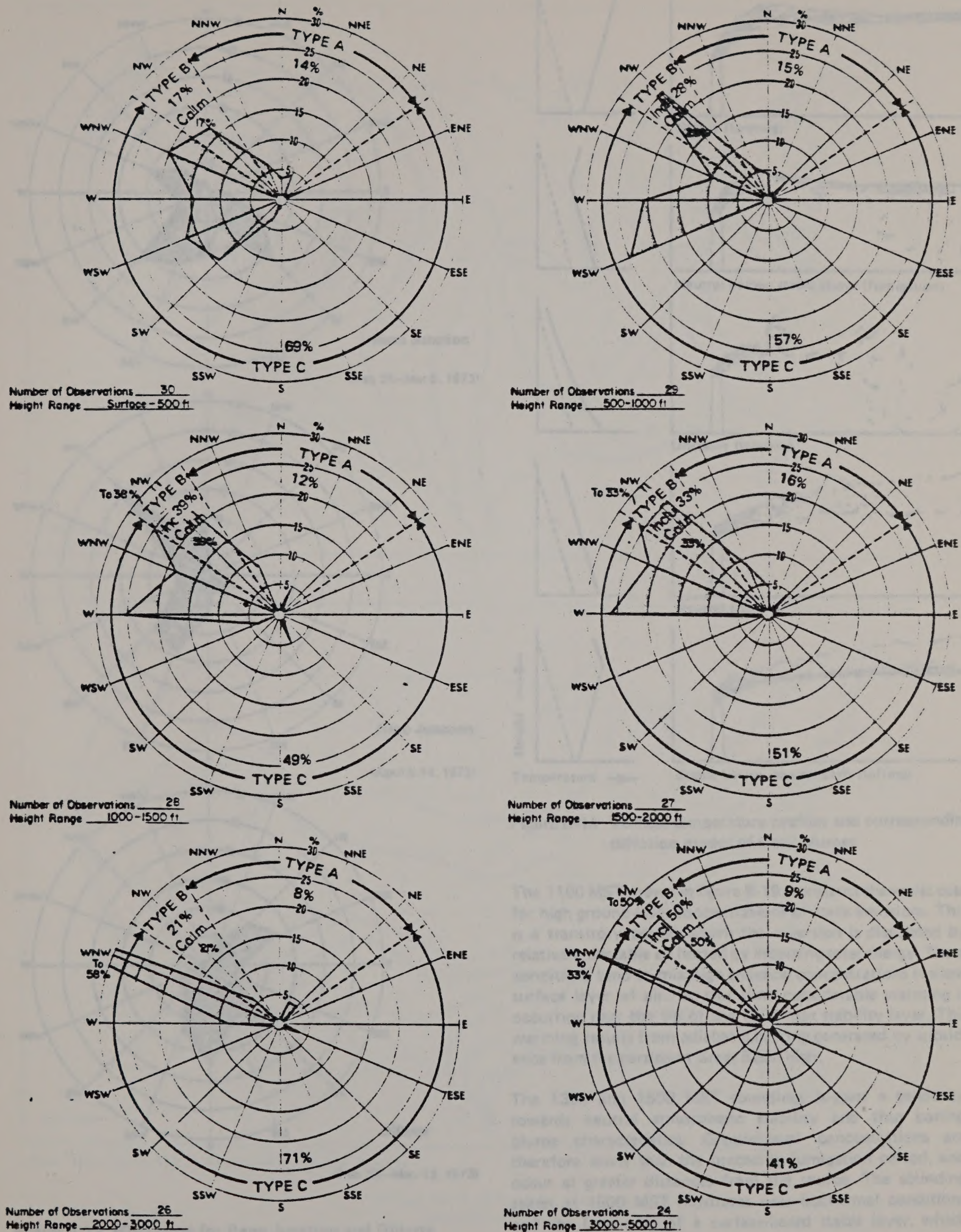


Figure B-12 Two-level wind roses and corresponding speed-frequency categories at south plant site (December 1973)

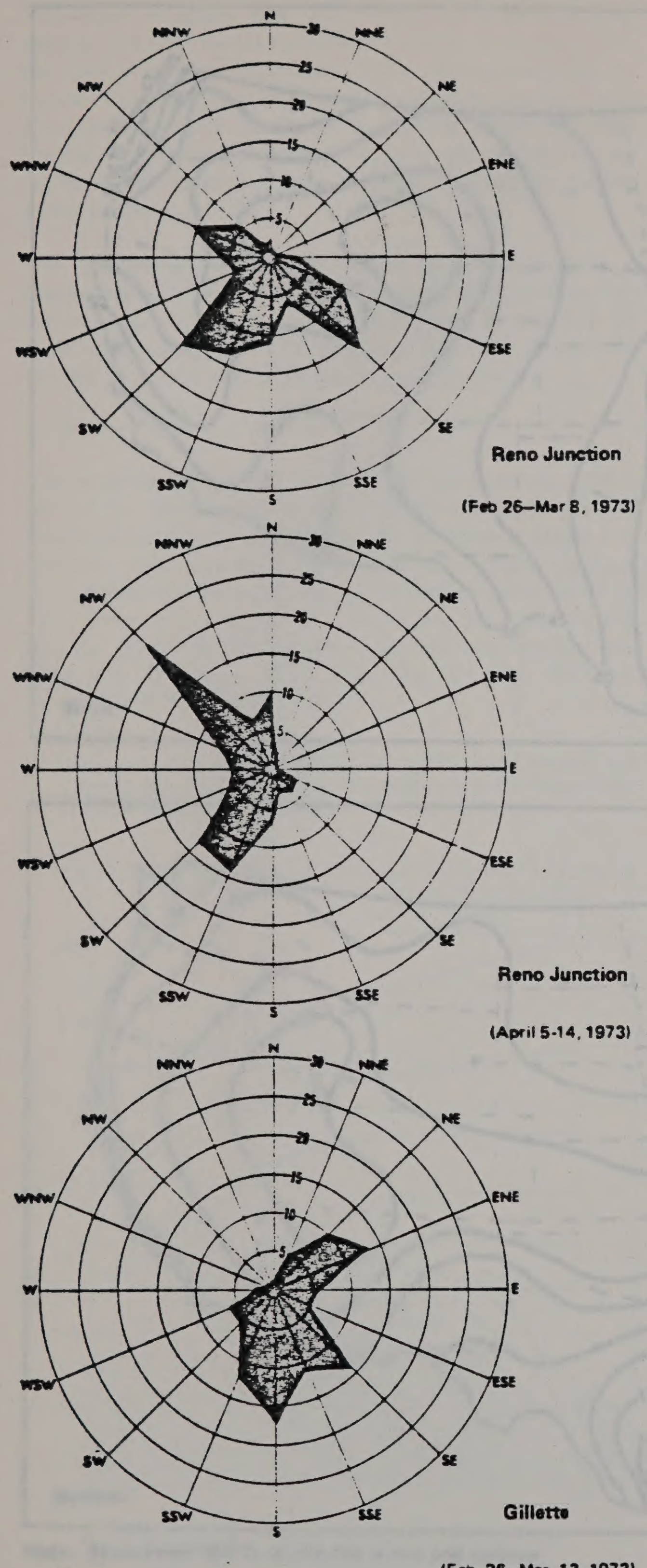


Figure B-13 Wind roses for Reno Junction and Gillette

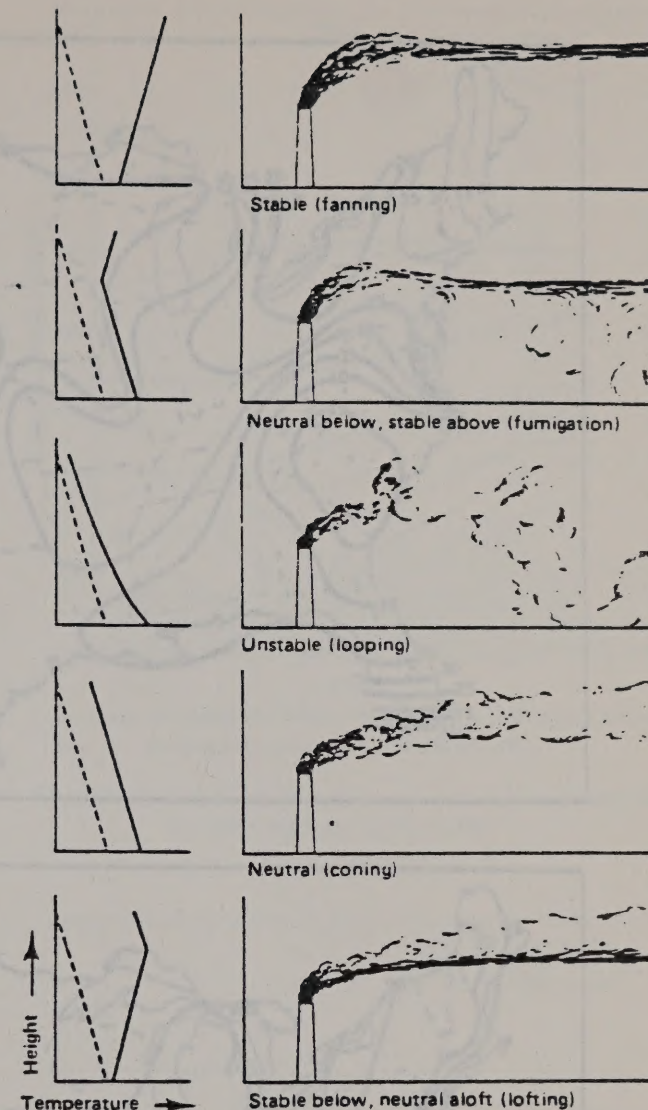
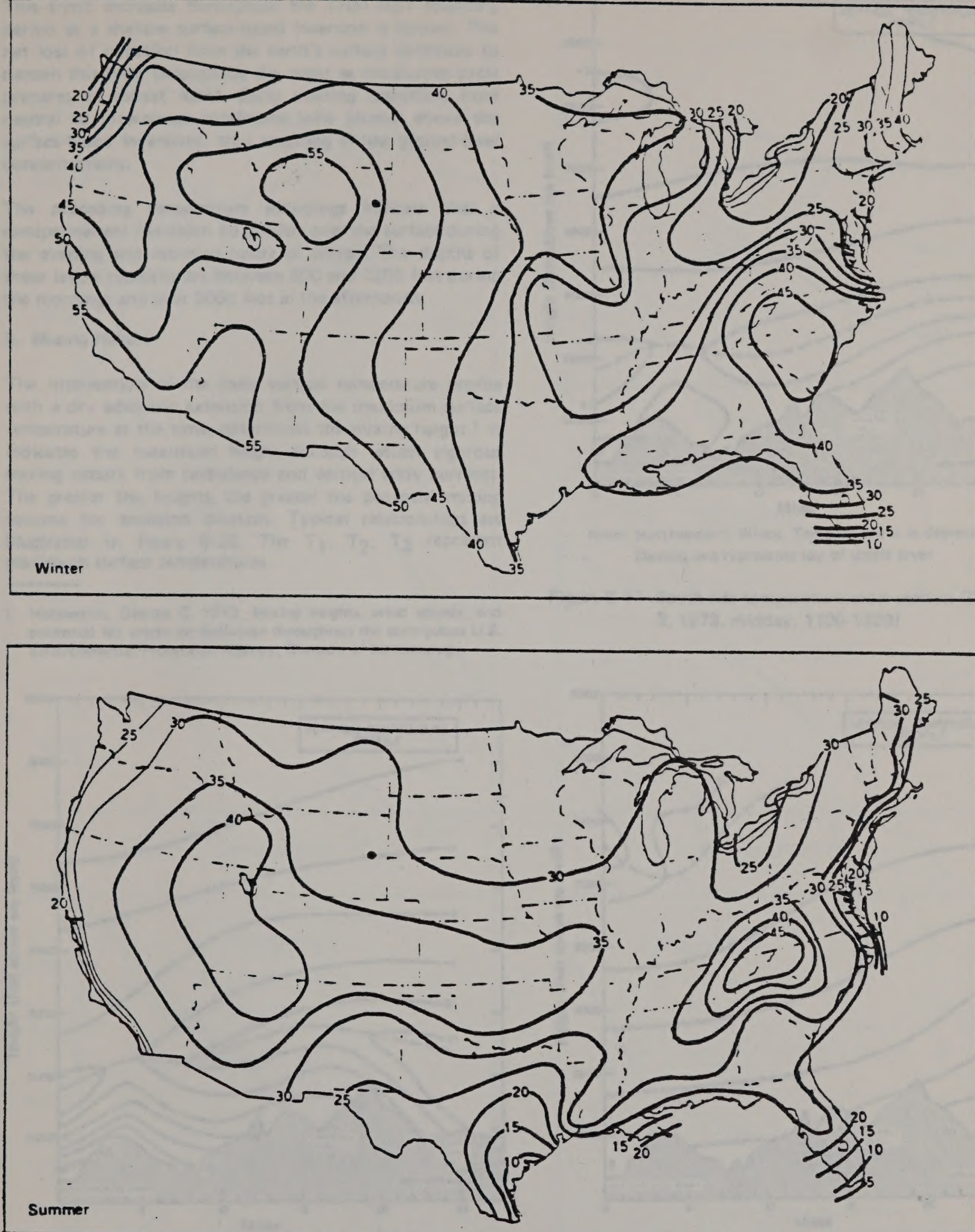


Figure B-14 Vertical temperature profiles and corresponding diffusion modes of stack plumes

The 1100 MST shown in figure B-19 represents the worst case for high ground-level concentrations of stack emissions. This is a transitory period where the inversion is dissipated by relatively unstable air heated by incoming solar energy. These conditions tend to mix high emission concentrations in a low surface layer of air. At this time considerable warming is occurring near the tip of the 1000-foot stability layer. This warming results from adiabatic heating generated by subsidence from the persistent Great Basin high.

The 1300 and 1500 MST soundings suggest a tendency towards neutral atmospheric stability and thus coning plume characteristics. Ground-level concentrations are therefore lower than the preceding fumigation period, and occur at greater distances from the source. The sounding taken at 1500 MST illustrates near isothermal conditions and the beginning of a surface-based stable layer, which

C-102



Note: Based below 500 ft. during the winter and summer

Source: Hasler, C.R., 1961. Low-level inversion frequency in the contiguous United States. Monthly Weather Rev. 89(9):319-339.

Figure B-15 Percentage frequency of occurrence of inversions or isothermal conditions

results from later afternoon cooling of the earth's surface. This trend increases throughout the 1700 MST sounding period as a shallow surface-based inversion is formed. The net loss of radiation from the earth's surface continues to deepen this layer throughout the night as the diurnal cycle prepares to repeat itself. Early evening transition from neutral to inversional conditions lofts plumes above the surface-based inversions, thus resulting in low ground-level concentrations.

The preceding temperature soundings indicate that a semipermanent inversion lid persists over the surface during the evening and morning hours of winter. The depths of these layers typically are between 500 and 1200 feet during the mornings and over 3000 feet in the afternoons.

b. Mixing Height

The intersection of the daily vertical temperature profile with a dry adiabatic extension from the maximum surface temperature at the time, determines the mixing height.[1] It indicates the maximum height through which vigorous mixing occurs from turbulence and vertical eddy currents. The greater the heights, the greater the potential mixing volume for emission dilution. Typical relationships are illustrated in figure B-20. The T_1, T_2, T_3 represent maximum surface temperatures.

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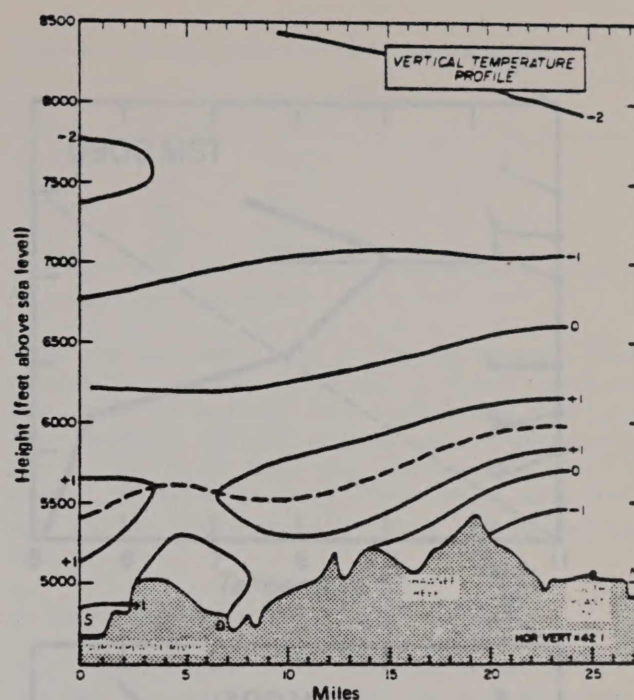
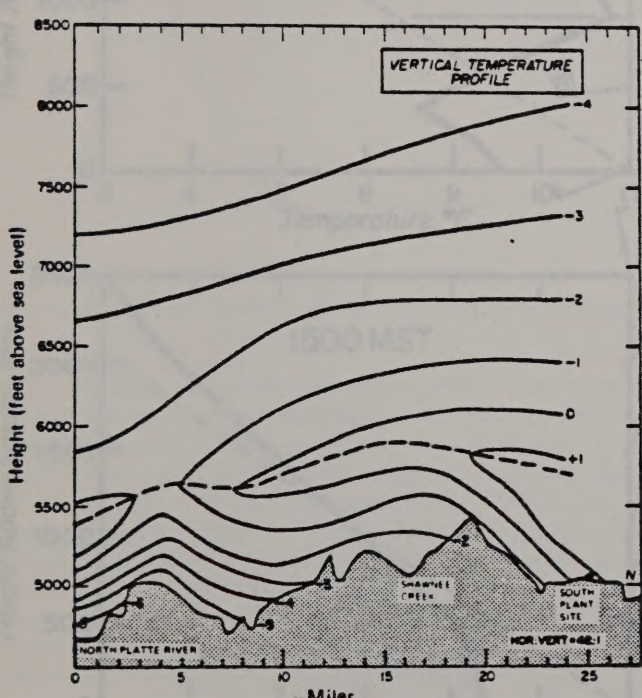
1 Holzworth, George C. 1972. Mixing heights, wind speeds, and potential for urban air pollution throughout the contiguous U.S. Environmental Protection Agency, Division of Meteorology.



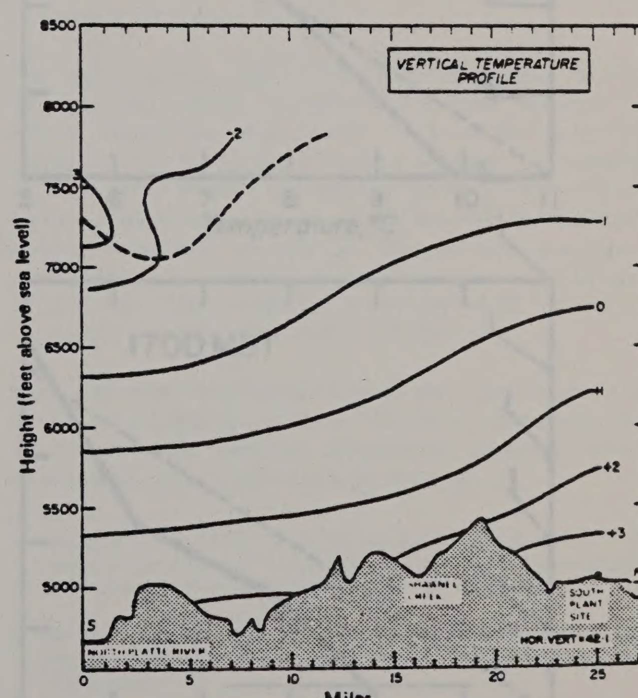
Note: Northeasterly Winds. Temperature is in degrees Centigrade. Dashed line represents top of stable layer

Figure B-17 South site temperature cross section (December 3, 1973, midday, 1100-1300)



Note: Northeasterly winds. Temperature is in degrees Centrigrade. Dashed line represents top of stable layer.

Figure B-16 South site temperature cross section (December 3, 1973, morning, 0800-1000)



Note: Northwesterly winds. Temperature is in degrees Centigrade. Dashed line represents top of stable layer.

Figure B-18 South site temperature cross section (December 3, 1973, afternoon, 1400-1600)

C-104

results from later afternoon cooling of the earth's surface. This trend increased throughout the 1700 MST sounding period as a shallow surface-based inversion is formed. The net loss of radiation from the earth's surface continues to deepen this layer throughout the night as the diurnal cycle prepares to repeat itself. Early evening transition from neutral to inversional conditions lofts plumes above the surface-based inversions, thus resulting in low ground-level concentrations.

The preceding temperature soundings indicate that a semipermanent inversion lies persistently over the surface during the evening and morning hours of winter. The depths of these layers typically are between 500 and 1200 feet during the mornings and over 3000 feet in the afternoons.

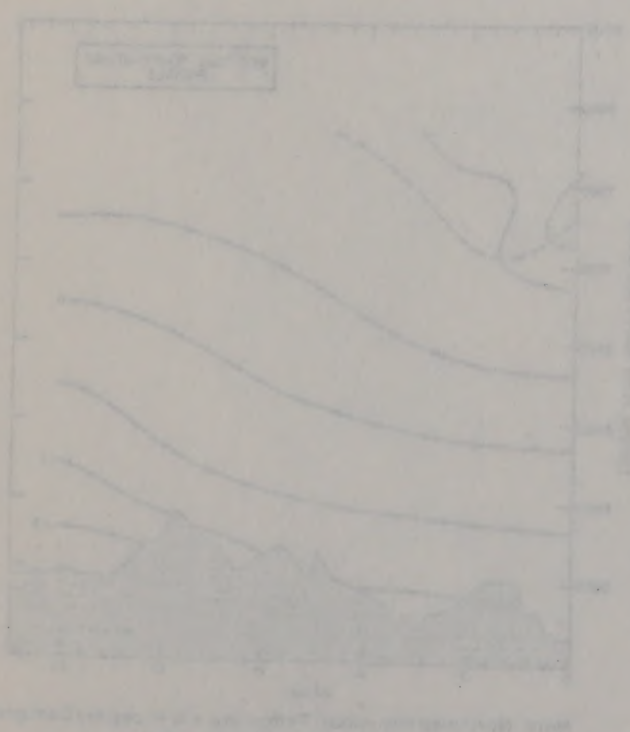
b. Mixing Height

The intersection of the daily vertical temperature profile with a dry adiabatic extension from the maximum surface temperature at the time, determines the mixing height.[1] It indicates the maximum height through which vigorous mixing occurs from turbulence and vertical eddy currents. The greater the heights, the greater the potential mixing volume for emission dilution. Typical relationships are illustrated in figure B-20. The T_1, T_2, T_3 represent maximum surface temperatures.

1. Holzworth, George C. 1972. Mixing heights, wind speeds, and potential for urban air pollution throughout the contiguous U.S. Environmental Protection Agency, Division of Meteorology.

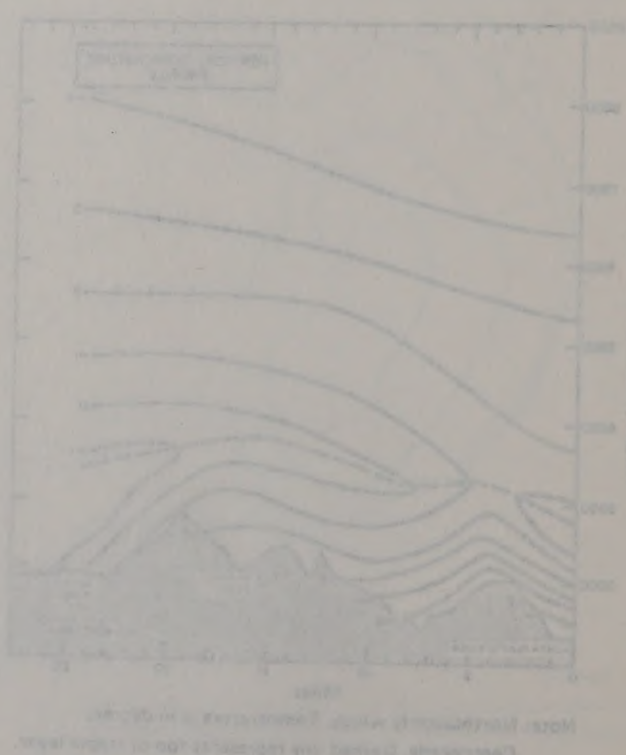
Note: Horizontally, miles. Temperature is in degrees Centigrade. Dashed line represents top of stable layer.

Figure B-17. South rim temperature cross section (December 3, 1973, midday, 1100-1200)



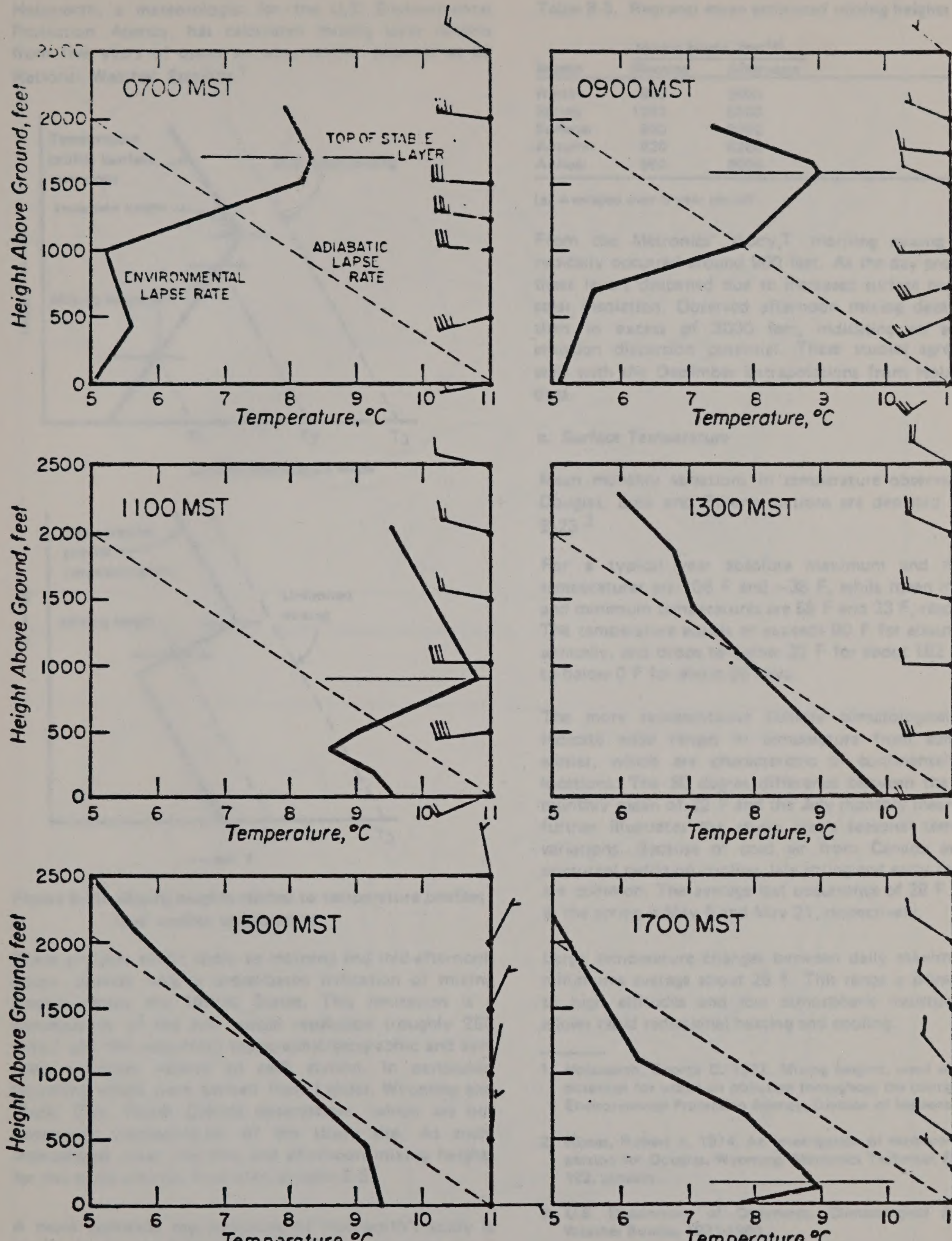
Note: Horizontally, miles. Temperature is in degrees Centigrade. Dashed line represents top of stable layer.

Figure B-18. South rim temperature cross section (December 3, 1973, afternoon, 1400-1600)



Note: Horizontally, miles. Temperature is in degrees Centigrade. Dashed line represents top of stable layer.

Figure B-16. South rim temperature cross section (December 3, 1973, morning, 0800-1000)



Note: At Marwitz Site. One-full barb equals ten knots.

Figure B-19 Diurnal formation and deterioration of a January nocturnal stable layer at the Martwitz site

Holzworth, a meteorologist for the U.S. Environmental Protection Agency, has calculated mixing layer heights from five years of upper air observations acquired at 62 National Weather Stations.[1]

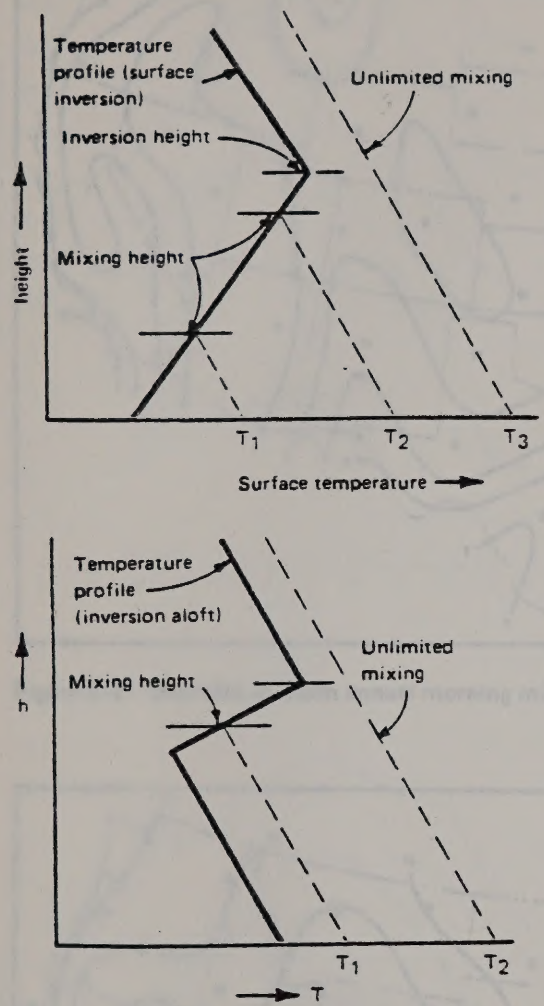


Figure B-20 Mixing heights related to temperature profiles and surface temperature

These analyses which apply to morning and mid-afternoon hours, provide only a broad-based indication of mixing heights across the United States. This limitation is a consequence of the low spatial resolution (roughly 250 miles) and the associated topographic/geographic and synoptic variances related to each station. In particular, Wyoming values were derived from Lander, Wyoming and Rapid City, South Dakota observations, which are not necessarily representative of the study site. As such, interpolated mean morning and afternoon mixing heights for the study area are illustrated in table B-5.[1]

A more complete representation of Holzworth's study is shown in figures B-21 and B-22 which illustrate mean annual morning and afternoon mixing heights along with weather station locations. Greatest mixing occurs in the afternoon, and it peaks during the summer months.

Table B-5. Regional mean estimated mixing heights

	Mixing height, feet[a]	
Season	Morning	Afternoon
Winter	920	3600
Spring	1280	8500
Summer	950	9900
Autumn	820	6200
Annual	980	6900

(a) Averaged over 5 year period

From the Metronics' study,[2] morning mixing heights typically occurred around 900 feet. As the day progressed, these layers deepened due to increased surface heating by solar insolation. Observed afternoon mixing depths were then in excess of 3000 feet, indicating an excellent emission dispersion potential. These studies agree fairly well with the December extrapolations from Holzworth's data.

c. Surface Temperature

Mean monthly variations in temperature observed at the Douglas, Lusk and Gillette stations are depicted in figure B-23.[3]

For a typical year absolute maximum and minimum temperatures are 106 F and −38 F, while mean maximum and minimum temperatures are 58 F and 33 F, respectively. The temperature equals or exceeds 90 F for about 29 days annually, and drops to below 32 F for about 182 days and to below 0 F for about 26 days.

The more representative Gillette climatological records indicate wide ranges in temperature from summer to winter, which are characteristic of continentally-bound locations. The 50 degree difference between the January monthly mean of 22 F and the July monthly mean of 72 F further illustrates the study area's seasonal temperature variations. Because of cold air from Canada and rapid nocturnal radiation cooling, late spring and early fall freezes are common. The average last occurrence of 28 F and 32 F in the spring is May 5 and May 21, respectively.

Large temperature changes between daily maximums and minimums average about 25 F. This range is primarily due to high altitudes and low atmospheric moisture, which allows rapid radiational heating and cooling.

1 Holzworth, George C. 1972. Mixing heights, wind speeds, and potential for urban air pollution throughout the contiguous U.S. Environmental Protection Agency, Division of Meteorology.

2 Nunes, Robert A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Technical Report no. 192. January.

3 U.S. Department of Commerce. Climatological Summaries. Weather Bureau, 1931-1960.

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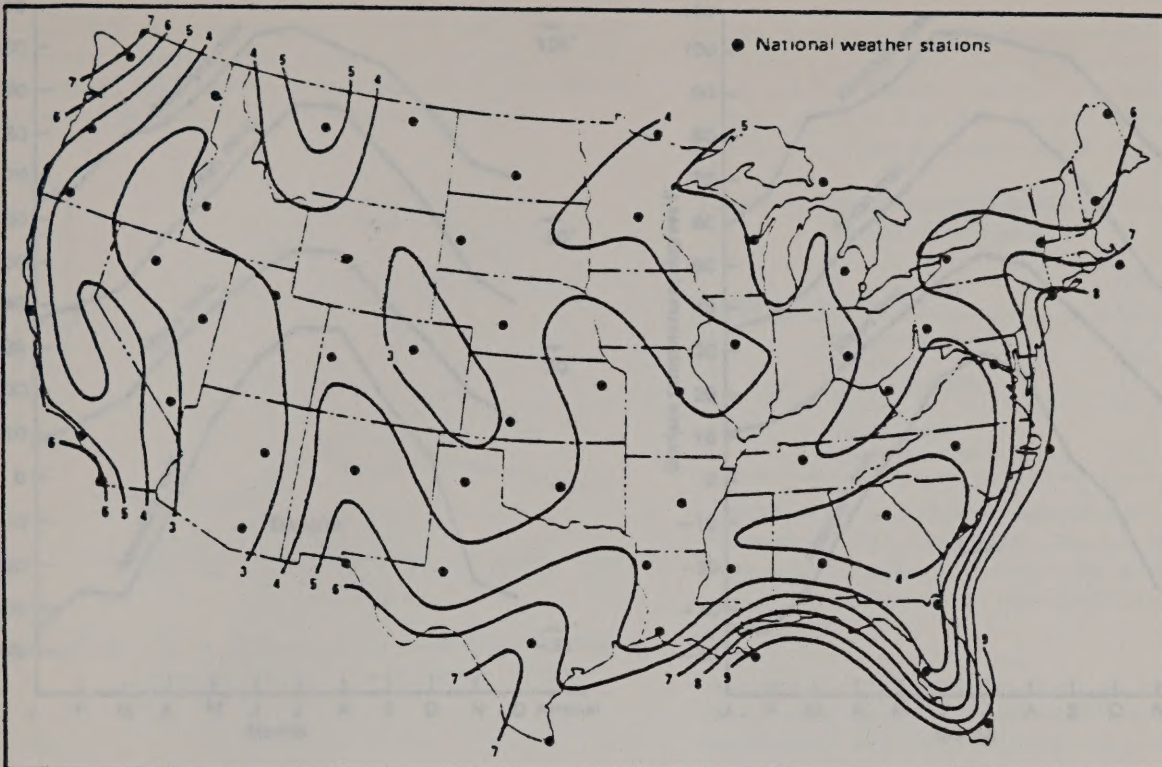

Figure B-21 Isopleths of mean annual morning mixing heights

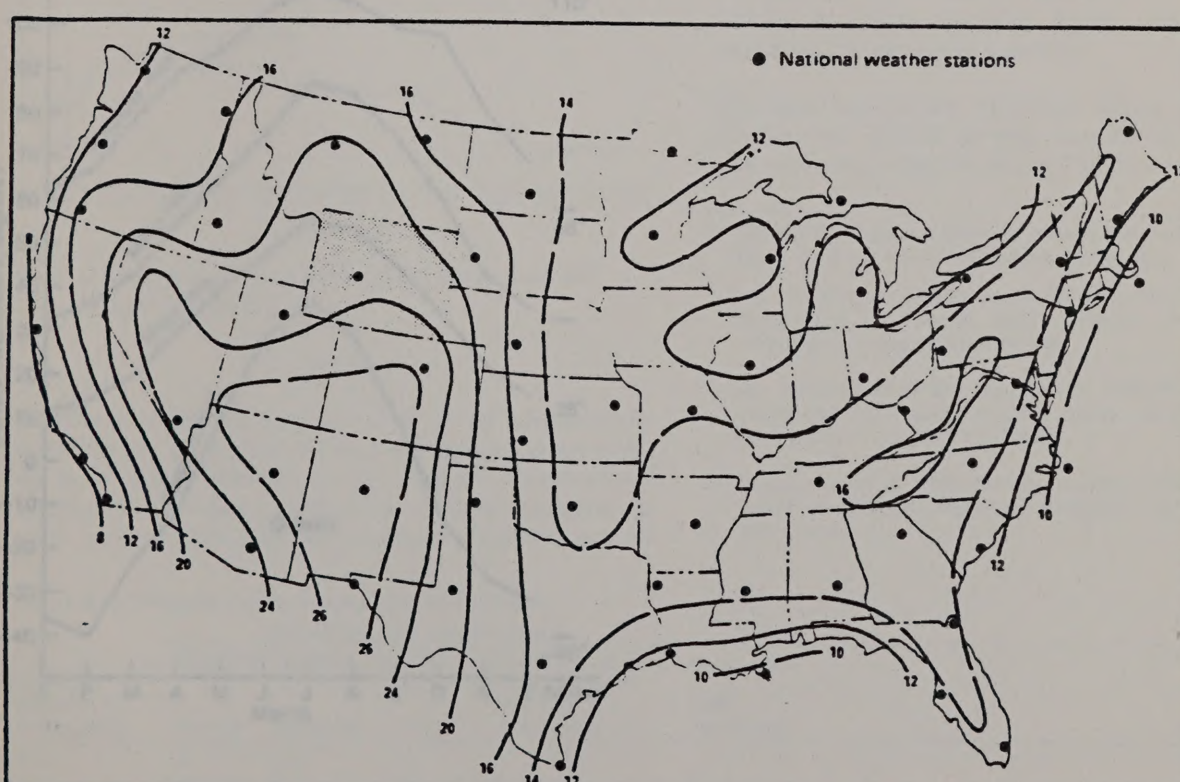

Figure B-22 Isopleths of mean annual afternoon mixing heights

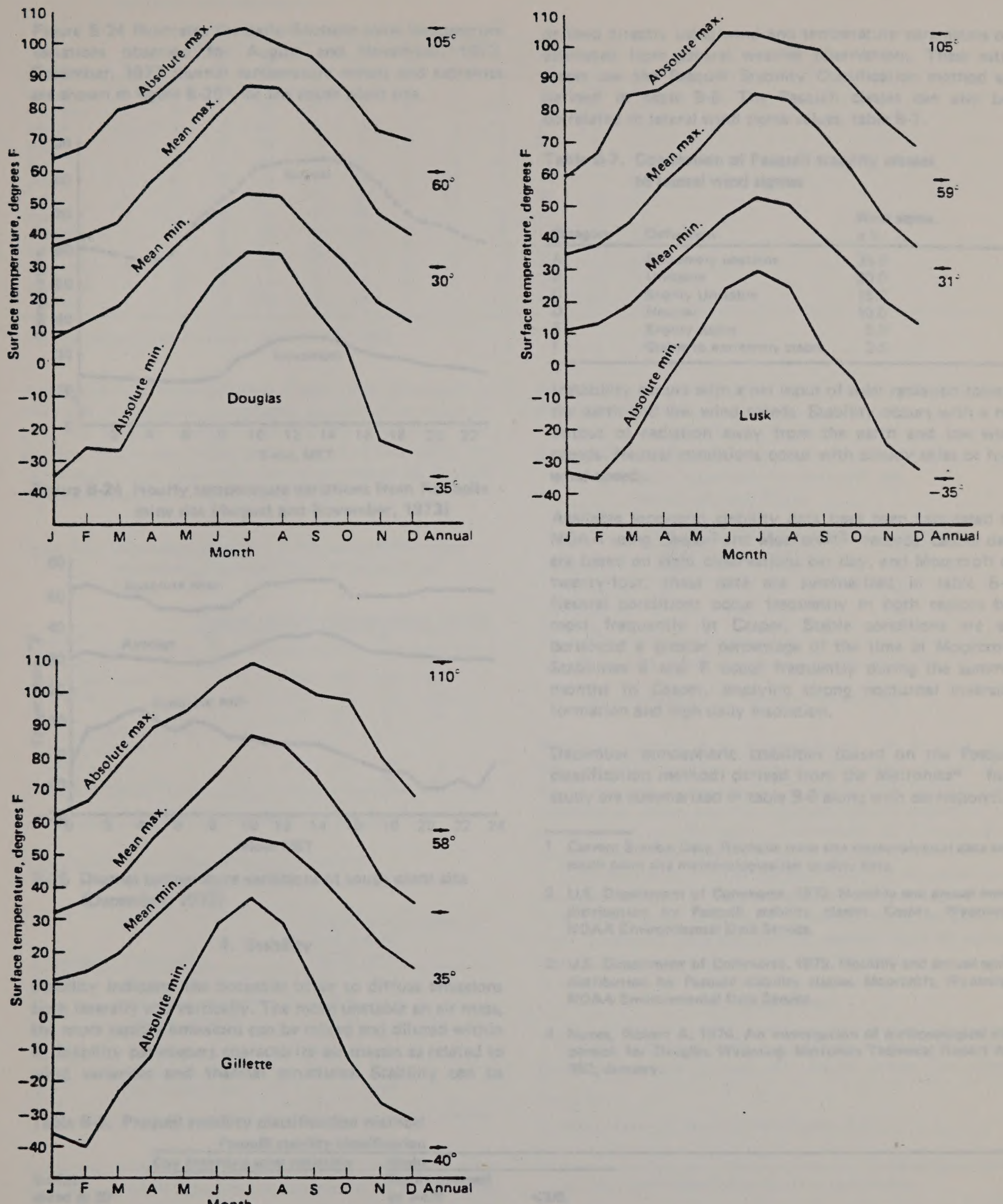

Figure B-23 Monthly temperature means and extremes for Douglas, Lusk, and Gillette

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Figure B-24 illustrates the daily Rochelle mine temperature variations observed for August and November, 1973. December, 1973 diurnal temperature means and extremes are shown in figure B-25[1] for the south plant site.

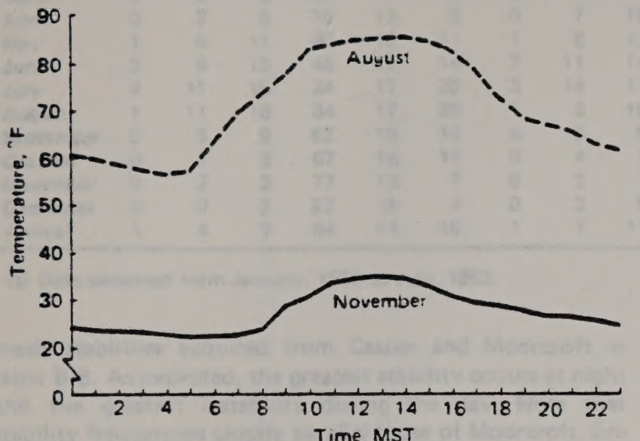
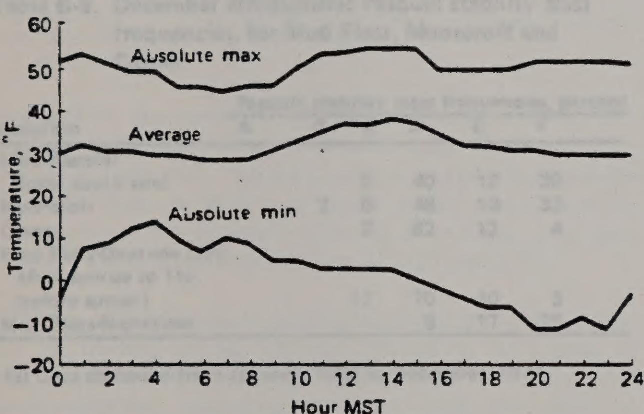


Figure B-24 Hourly temperature variations from Rochelle mine site (August and November, 1973)



B-25 Diurnal temperature variations at south plant site (December, 1973)

4. Stability

Stability indicates the potential of air to diffuse emissions both laterally and vertically. The more unstable an air mass, the more rapidly emissions can be mixed and diluted within it. Stability parameters characterize air masses as related to wind variances and thermal structures. Stability can be defined directly using wind and temperature parameters or estimated from general weather observations. These estimates use the Pasquill Stability Classification method as defined in table B-6. The Pasquill classes can also be correlated to lateral wind sigma values, table B-7.

Table B-6. Pasquill stability classification method

	Pasquill stability classification				
	Day incoming solar radiation			Night	
Surface speed at 30' height, mph	Strong	Moderate	Slight	Thinly overcast or >4/8 cloud cover	<3/8 cloud cover
<4	A	A-B	B		
4-7	A-B	B	C	E	F
7-11	B	B-C	C	D	E
11-13	C	C-D	D	D	D
>13	C	D	D	D	D

Table B-7. Correlation of Pasquill stability classes to lateral wind sigmas

Category	Definition	Wind sigma, σ θ
A	Extremely unstable	25.0°
B	Unstable	20.0°
C	Slighly Unstable	15.0°
D	Neutral	10.0°
E	Slighly stable	5.0°
F	Stable to extremely stable	2.5°

Instability occurs with a net input of solar radiation toward the earth and low wind speeds. Stability occurs with a net output of radiation away from the earth and low wind speeds. Neutral conditions occur with cloudy skies or high wind speeds.

Available long-term stability data have been calculated by NOAA using Casper[2] and Moorcroft[3] records. Casper data are based on eight observations per day, and Moorcroft on twenty-four; these data are summarized in table B-8. Neutral conditions occur frequently in both regions but most frequently in Casper. Stable conditions are experienced a greater percentage of the time at Moorcroft. Stabilities E and F occur frequently during the summer months in Casper, implying strong nocturnal inversion formation and high daily insolation.

December atmospheric stabilities (based on the Pasquill classification method) derived from the Metronics[4] field study are summarized in table B-9 along with corresponding

1 Current Station Data. Rochelle mine site meteorological data and south plant site meteorological/air quality data.

2 U.S. Department of Commerce. 1973. Monthly and annual wind distribution by Pasquill stability classes. Casper, Wyoming. NOAA Environmental Data Service.

3 U.S. Department of Commerce. 1973. Monthly and annual wind distribution by Pasquill stability classes. Moorcroft, Wyoming. NOAA Environmental Data Service.

4 Nunes, Robert A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Technical Report no. 192, January.

Table B-8. Atmospheric Pasquill stability class frequencies for Casper and Moorcroft

	Pasquill stability class frequencies, percent [(a)]											
	Casper						Moorcroft					
Month	A	B	C	D	E	F	A	B	C	D	E	F
January	0	0	1	85	10	4	0	3	9	45	10	33
February	0	0	3	78	13	6	0	5	12	39	10	34
March	0	2	3	81	10	5	0	7	11	47	8	26
April	0	2	6	70	13	8	0	7	10	53	9	20
May	1	5	11	60	12	11	1	8	13	52	9	16
June	2	9	12	48	15	14	2	11	14	43	9	20
July	4	11	15	34	17	20	3	14	17	32	9	24
August	1	11	16	34	17	20	1	3	18	30	8	29
September	0	5	9	52	19	16	0	9	8	52	9	22
October	0	1	5	67	16	11	0	4	7	55	11	23
November	0	2	3	77	13	7	0	2	7	31	13	28
December	0	0	2	82	12	4	0	2	6	48	13	32
Annual	1	4	7	64	14	10	1	7	11	46	10	25

(a) Data compiled from January, 1950 to July, 1952.

mean stabilities acquired from Casper and Moorcroft in table B-8. As expected, the greatest stability occurs at night and the greatest instability during the day. Note that stability frequencies closely parallel those of Moorcroft. Environmental lapse rates can also be correlated to Pasquill stability categories shown in table B-10.[1]

Table B-9. December atmospheric Pasquill stability class frequencies, for Mud Flats, Moorcroft and Casper

	Pasquill stability class frequencies, percent					
Location	A	B	C	D	E	F
Mud Flats(a) (near south site)			8	40	13	39
Moorcroft		2	6	48	13	32
Casper			2	82	12	4
Mud Flats-Daytime (1hr. after sunrise to 1hr. before sunset)			17	70	10	3
Mud Flats-Nighttime				8	17	75

(a) Data compiled from January, 1967 to December, 1971.

Table B-10. Correlation of Pasquill stability classes to environmental lapse rate

Categories	Definitions	Environmental lapse rate, degrees C/100 meters
A	Extremely unstable	<-1.9
B	Moderately unstable	-1.9 to -1.7
C	Slightly unstable	-1.7 to -1.5
D	Neutral	-1.5 to -0.5
E	Slightly stable	-0.5 to 1.5
F	Moderately stable	1.5 to 4.0
G	Extremely stable	>4.0

December stabilities based on meteorological station delta temperature (ΔT) data are summarized in tables B-11 and B-12. Table B-11 lists total frequency of stability classes and compares these classes with corresponding Moorcroft and Casper data. Again observe the marked similarity of the south site to Moorcroft data. Table B-12 lists daily stability class frequencies.[2]

Table B-11. Comparison of December Pasquill stability class frequencies for the south site, Moorcroft, and Casper

	Pasquill stability class frequencies, percent		
Location	Unstable class A, B, C	Neutral Class D,E	Stable class F, G
South site (a)	4	61	36
Moorcroft (b)	8	61	32
Casper (b)	2	94	4

(a) Taken from 5 days of observations in December, 1973.[3]

(b) Data compiled over 30 months of observations.

Stabilities derived from meteorological station data are grouped into only three categories. This arises because the charts can only be read to 0.1 C and once the temperature differential, taken over the 30 meter sensor separation is extrapolated to 100 meters, a minimum .33 C resolution results. The other approach, reducing table B-10 values of 1 C/10 meters to 1 C/30 meters, results in a similar but reversed situation as defined stability temperature bands now exceed chart resolution. In general, stabilities derived from tower ΔT data may not be representative of atmospheric stabilities near expected stack heights.

5. Precipitation

Annual precipitation levels range between 12 and 16 inches. Snowfall averages between 35 and 65 inches. The mean

1 Safety Guide 23. Atomic Energy Commission.

2 Current station data. Rochelle mine site meteorological data and south plant site meteorological air quality data.

3 Nunes, Robert A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Technical Report no. 192. January.

Table B-12. Diurnal Pasquill stability class frequencies (December, 1973)

Hour	Pasquill stability class frequencies, percent[a] Unstable class A, B, C	Neutral class D, E	Stable class F, G
01	0	52	48
02	0	57	43
03	0	61	39
04	0	65	35
05	0	48	52
06	0	52	48
07	0	64	36
08	0	65	35
09	4	74	22
10	0	91	9
11	17	70	13
12	22	74	4
13	22	70	8
14	22	70	8
15	0	96	4
16	4	83	13
17	0	50	50
18	0	42	58
19	0	46	54
20	0	42	58
21	0	33	67
22	0	38	62
23	0	62	38
24	0	58	42

(a) Reduced from 23 days of south site ΔT meteorological station data

number of days where precipitation equals or exceeds 0.1 inches is 35, and where snowfall equals or exceeds 1.5 inches is eight days. The mean annual precipitation isogram for the state is shown in figure B-26. Mean monthly precipitation and snowfall recorded at Douglas, Lusk and Gillette stations are shown in figures B-27 and B-28.[1]

Gillette climatological records indicate normal precipitation to be lightest during February, increasing to a peak in mid-June. Late spring and summer rains are associated with southeasterlies, importing moisture from the Gulf of Mexico.

During the last half of June, precipitation decreases until a low is reached in August, a secondary increase in mid-September, which tapers off again until February. Normally, about 46 percent of the annual precipitation (6.40 inches) falls between the average 32 F freeze-free dates, and about 56 percent (7.83 inches) falls between the average 28 F freeze-free dates. Snow and sleet may be correlated with a cut-off low at 500 mb over the central United States, coupled with frontogenisus over the Northern Great Plains. Mean monthly totals of snow and sleet are shown in figure B-28.[1]

Most summertime precipitation observed at the Rochelle mine occurred during two periods, the pre-dawn hours between 0300-0500 MST, and the late afternoon hours between 1500-1800 MST.[2]

The major daytime peak may result from strong summertime insolation at the mine's surface, which induces instability convection and adiabatic cooling. The nighttime maximum probably arises from instability induced by radiational cooling of the cloud tops. Wintertime maximums also indicate a significant but lesser nighttime peak, probably caused again by radiational cooling above the cloud tops. Other hourly precipitation probably occurs from the random arrival of synoptic systems overcoming these daily effects. Figure B-29 summarizes these observations for July and October, 1973.

The 30-year climatic sample from 1931 to 1960 averaged from Douglas, Lusk and Gillette indicates a mean annual precipitation total of 14.2 inches. The maximum was about 18.5 inches and a minimum of slightly over 8.0 inches.

Table B-13 summarizes durations and frequencies of short-term rainfall intensities.[1] This information is useful for assessing the occurrence of runoff, which for this region is less than 0.07 inches. Another parameter of interest is the ratio of runoff to total precipitation which is, for the study area, less than 0.005.[3]

Table B-13. Short duration maximum rainfall intensities for selected return periods[4]

Duration of precipitation, hours	Maximum rainfall intensity in inches, by return period (expected recurrence) 2 Years	5 Years	10 Years	25 Years	50 Years
.5	.7	1.1	1.3	1.5	1.7
1	1.0	1.3	1.6	1.9	2.1
2	1.1	1.5	1.7	2.2	2.4
3	1.2	1.6	1.9	2.3	2.6
6	1.3	1.8	2.2	2.6	2.9
12	1.6	2.1	2.5	2.9	3.3
24	1.8	2.4	2.9	3.3	3.8

The net storage or loss of water for a regional hydrological system is a function of the balance between the input of water by precipitation and output of moisture by evaporation. The dryness of the region is reflected by the precipitation minus potential evapotranspiration. Figure B-30 shows the monthly precipitation and evapotranspiration differences observed at the three climatic stations representative of the region.[5] This figure indicates that the annual precipitation-evaporation budget for this region has a deficit of about 9.1 inches.

1 U.S. Department of Commerce. Climatological summaries. Weather Bureau, 1931-1960.

2 Metronics Associates, Inc., 1973. Selected Wyoming Climatological Data April.

3 Sellers, William D. 1969 Physical climatology. Third edition.

4 Based on values which are extracted from "Weather Bureau Technical Paper No. 40."

5 Metronics Associates, Inc. Selected Wyoming climatological data, a compilation of U.S. Weather Bureau meteorological and climatological records observed from 1931-1960.

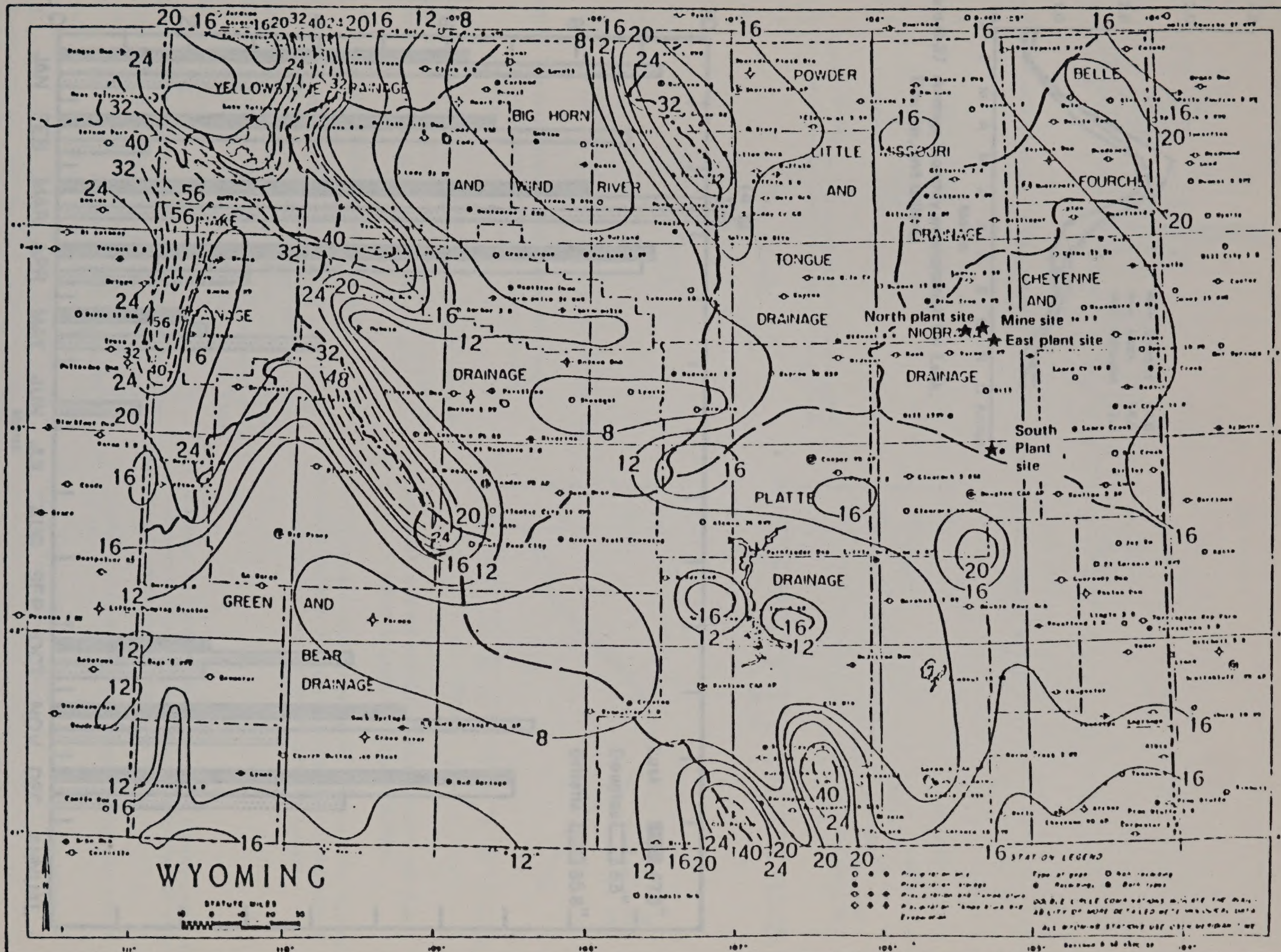


Figure B-26 Mean annual precipitation isogram for Wyoming (1931-1955)

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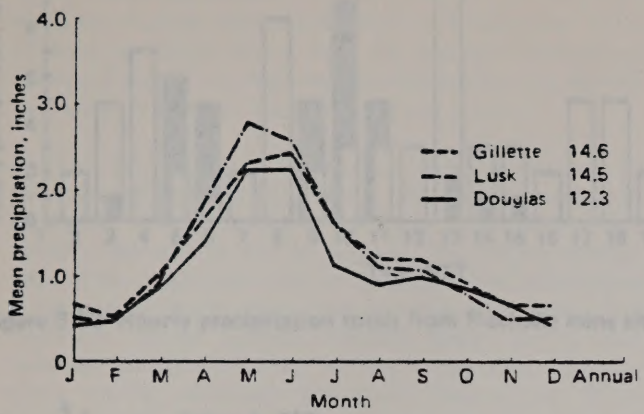

Figure B-27 Average monthly precipitation for Lusk, Douglas, and Gillette

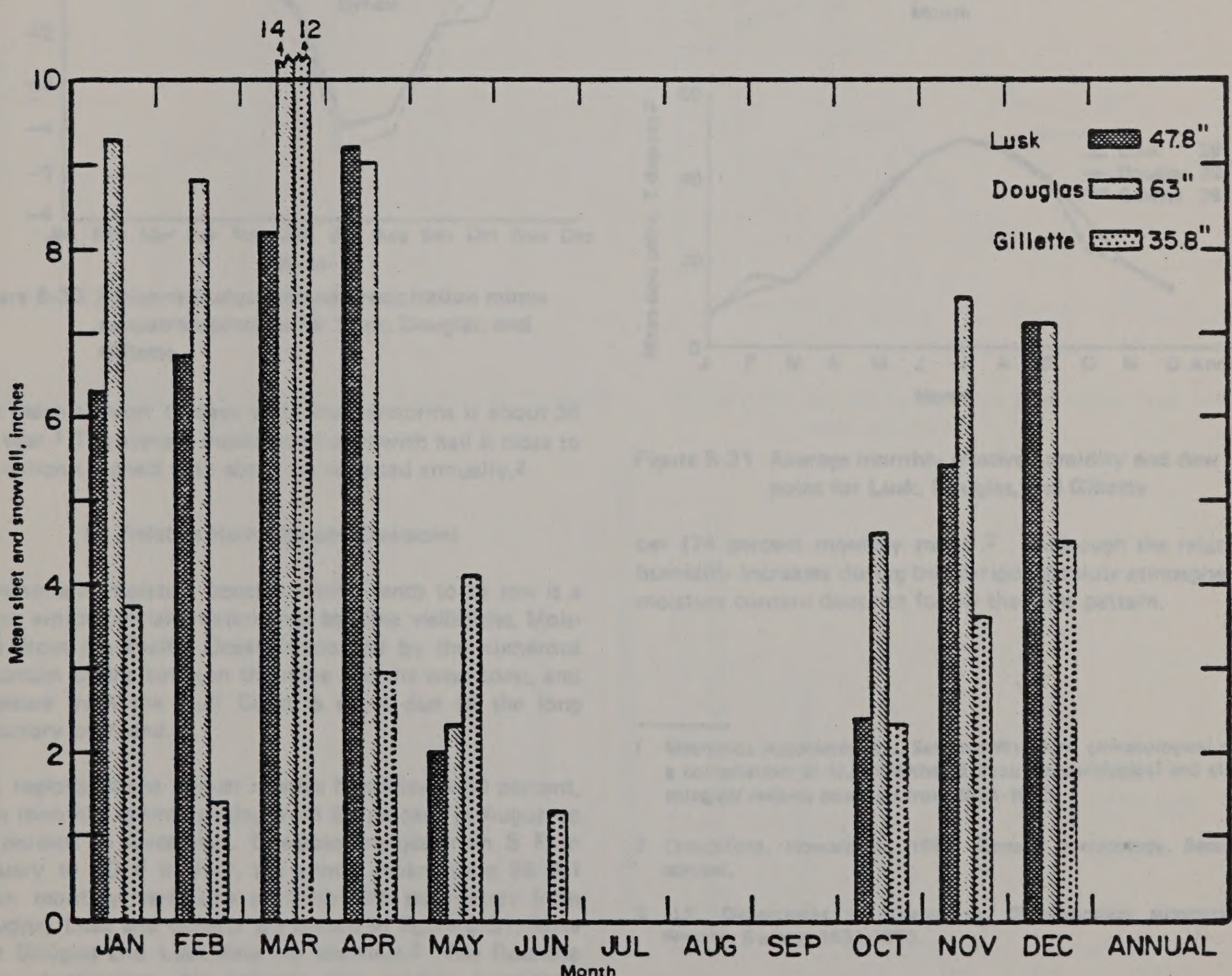

Figure B-28 Mean monthly snowfall for Lusk, Douglas, and Gillette

C-113

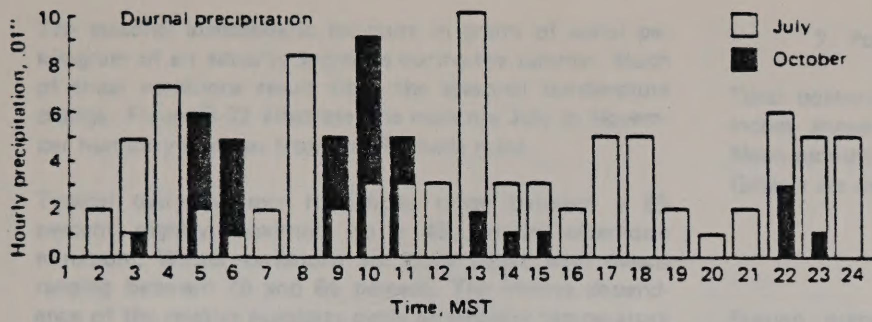

Figure B-29 Hourly precipitation totals from Rochelle mine site (July and October, 1973)

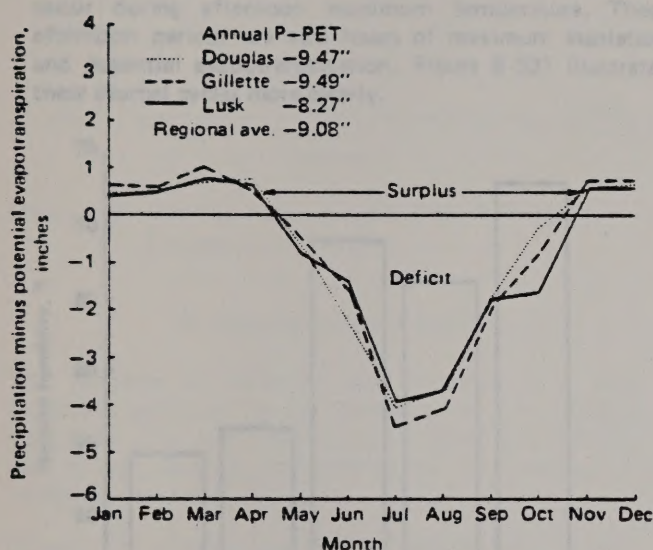

Figure B-30 Moisture budget-annual precipitation minus evapotranspiration for Lusk, Douglas, and Gillette

The mean number of days with thunderstorms is about 36 per year.[1] The average incidents of days with hail is close to the nation's highest with about six reported annually.[2]

6. Relative Humidity and Dewpoint

Atmospheric moisture content which tends to be low is a factor which partially determines baseline visibilities. Moisture from the Pacific Ocean is blocked by the numerous mountain chains between the mine and the west coast, and moisture from the Gulf Coast is slight due to the long trajectory over land.

The regional mean annual relative humidity is 60 percent, with monthly means ranging from 52 percent in August to 75 percent in December. Dewpoint ranges from 8 F in January to 50 F in July, the annual mean being 29 F.[1] Mean monthly variations of these two parameters from Douglas, Lusk and Gillette are shown in figure B-31. Note that Douglas and Lusk data are identical.[2] The Rochelle mine observations also indicate that relative humidities increase from July (54 percent monthly mean) to November (74 percent monthly mean).[3] Although the relative humidity increases during this period, absolute atmospheric moisture content does not follow the same pattern.

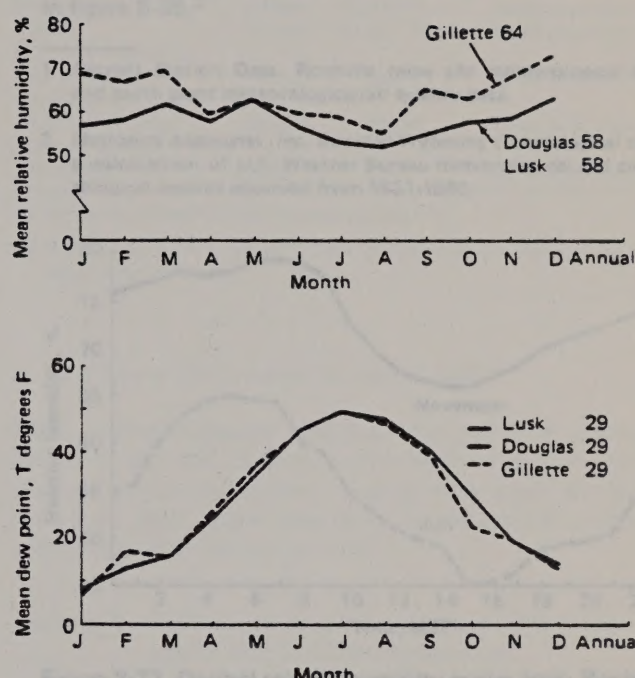

Figure B-31 Average monthly relative humidity and dew point for Lusk, Douglas, and Gillette

1 Metronics Associates, Inc. Selected Wyoming climatological data, a compilation of U.S. Weather Bureau meteorological and climatological records observed from 1931-1960.

2 Crinchfield, Howard J., 1966. General comatology. Second edition.

3 U.S. Department of Commerce. Climatological summaries. Weather Bureau, 1931-1960.

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The seasonal atmospheric moisture in grams of water per kilogram of air actually increases during the summer. Much of these variations result from the seasonal temperature change. Figure B-32 illustrates the monthly July to November humidity averages from the Rochelle mine.

Typical daily summer humidities range between a 65 percent nightly maximum to a 45 percent afternoon minimum. Winter variations are more slight, with means ranging between 79 and 66 percent. The inverse dependence of the relative humidity cycle on ambient temperature is reflected in the times of daily maxima and minima. The maximum relative humidity typically occurs during minimum air temperature while minimum humidities typically occur during afternoon maximum temperature. These afternoon periods are also hours of maximum insolation and potential evapotranspiration. Figure B-33[1] illustrates these diurnal cycles more clearly.

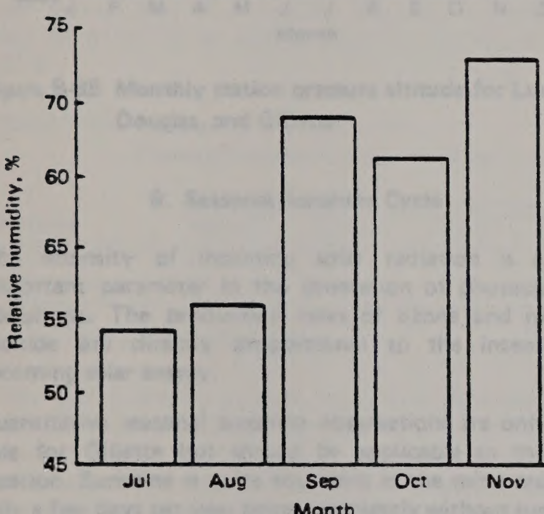

Figure B-32 Average monthly relative humidity at Rochelle mine site (1973)

7. Potential Evaporation and Transpiration

Total potential evaporation and transpiration is about 23 inches annually and is greatest during summer months. Mean monthly variations as observed at Douglas, Lusk, and Gillette are shown in figure B-34.[2]

8. Station Pressure Altitude

Station pressure altitude parameter when converted to pressure, is used in the calculation of plume rise from stack emission sources. Mean monthly pressure altitude variation recorded at Douglas,,Lusk, and Gillette stations are shown in figure B-35.[2]

1 Current Station Data. Rochelle mine site meteorological data and south plant meteorological/air quality data.

2 Metronics Associates, Inc. Selected Wyoming climatological date, a compilation of U.S. Weather Bureau meteorological and climatological records observed from 1931-1960.

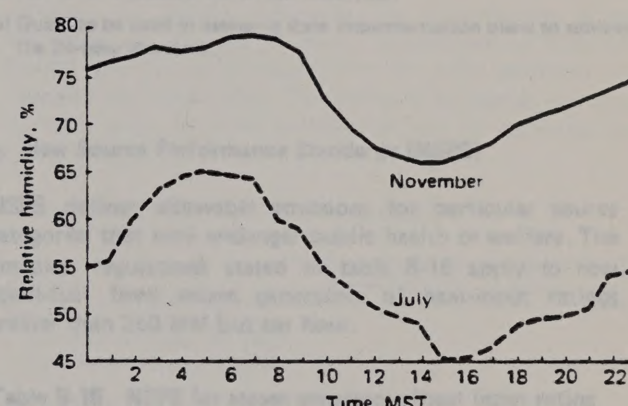

Figure B-33 Diurnal relative humidity cycles from Rochelle mine site (1973)

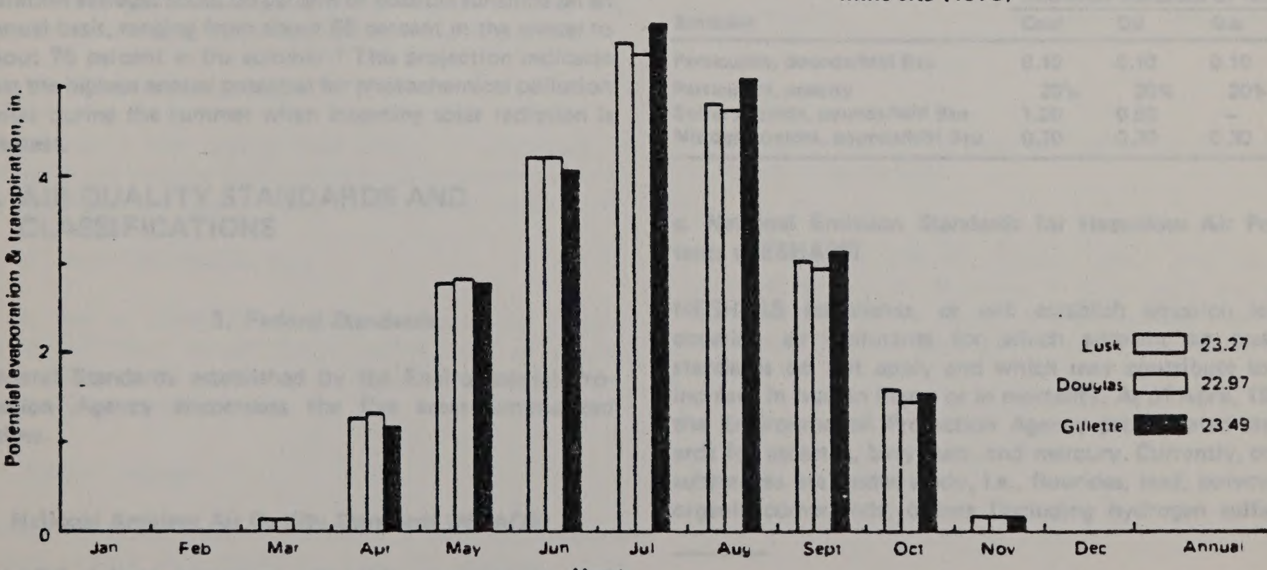

Figure B-34 Monthly totals of potential evapotranspiration for Lusk, Douglas, and Gillette

C-115

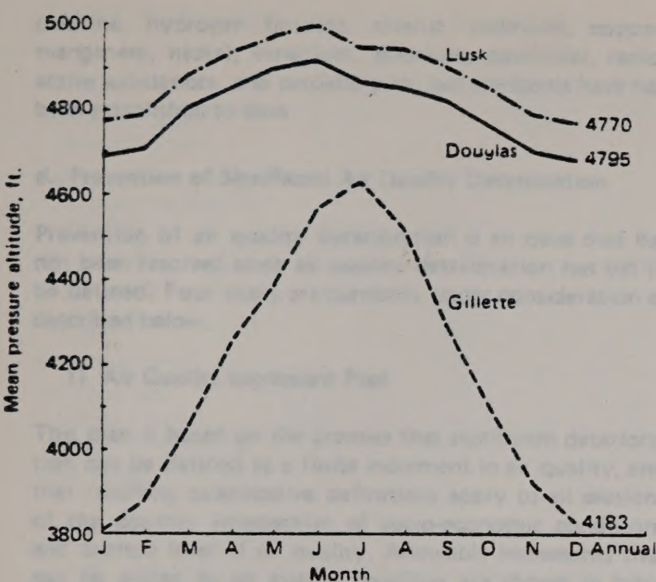

Figure B-35 Monthly station pressure altitude for Lusk, Douglas, and Gillette

9. Seasonal Sunshine Cycle

The intensity of incoming solar radiation is a most important parameter in the generation of photochemical pollutants. The production rates of ozone and nitrogen dioxide are directly proportional to the intensity of incoming solar energy.

Quantitative seasonal sunshine observations are only available for Gillette but should be applicable to the mine location. Sunshine is quite abundant in the mine area with only a few days per year being completely without sunshine. Although no instrumented record of sunshine duration is available at the mine site, it is estimated that sunshine duration averages about 65 percent of possible sunshine on an annual basis, ranging from about 55 percent in the winter to about 75 percent in the summer.[1] This projection indicates that the highest annual potential for photochemical pollution exists during the summer when incoming solar radiation is greatest.

B. AIR QUALITY STANDARDS AND CLASSIFICATIONS

1. Federal Standards

Federal Standards established by the Environmental Protection Agency encompass the five areas summarized below.

a. National Ambient Air Quality Standards (NAAQS)

NAAQS defines maximum allowable concentrations of emissions that can be experienced over a specific time period. As of 14 September 1973, standards were defined for those emissions applicable to this project and are listed in table B-14.

Table B-14. National Ambient Air Quality Standards

Emission	Average time	Human health (primary standards), $\mu g/m^3$	Public welfare (secondary standards), $\mu g/m^3$
Sulfur oxides (SO_2)	Annual	80	–
	24-Hour	365(a)	
	3-Hour	–	1,300(a)
Particulate matter	Annual	75	60(b)
	24-hour	260(a)	150(a)
Carbon monoxide (CO)	8-Hour	10,000(a)	Same as primary
	1-Hour	40,000(a)	Same as primary
Oxidants (corrected for NO_2, SO_2)	1-Hour	160(a)	Same as primary
Hydrocarbons (corrected for CH_4)	3-Hour	160(a)	Same as primary
Nitrogen oxides (as NO_2)	Annual	100	Same as primary

(a) Not to be exceeded more than once/year.

(b) Guide to be used in assessing state implementation plans to achieve the 24-hour standard.

b. New Source Performance Standards (NSPS)

NSPS defines allowable emissions for particular source categories that may endanger public health or welfare. The emission regulations stated in table B-15 apply to new fossil-fuel fired steam generators' of heat-input ratings greater than 250 MM But per hour.

Table B-15. NSPS for steam generators (heat input rating greater than 250 MM Btu per hour)

Emission	Allowable emissions by fuel: Coal	Oil	Gas
Particulate, pounds/MM Btu	0.10	0.10	0.10
Particulate, opacity	20%	20%	20%
Sulfur dioxide, pounds/MM Btu	1.20	0.80	–
Nitrogen oxides, pounds/MM Btu	0.70	0.30	0.30

c. National Emission Standards for Hazardous Air Pollutants (NESHAPS)

NESHPAS establishes, or will establish emission levels covering air pollutants for which ambient air quality standards do not apply and which may contribute to an increase in human illness or in mortality. As of April, 1973, the Environmental Protection Agency promulgated standards for asbestos, beryllium, and mercury. Currently, other substances are under study, i.e., flourides, lead, polycyclic organic compounds, ordors (including hydrogen sulfide),

1 U.S. Department of Commerce. Climatological summaries. Weather Bureau, 1931-1960.

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chlorine, hydrogen flouride, arsenic, cadmium, copper, manganese, nickel, vanadium, selenium, pesticides, radioactive substances, and aeroallergens; but standards have not been established to date.

d. Prevention of Significant Air Quality Deterioration

Prevention of air quality deterioration is an issue that has not been resolved since air quality deterioration has yet to be defined. Four plans are currently under consideration as described below.

1) Air Quality Increment Plan

This plan is based on the premise that significant deterioration can be defined as a finite increment in air quality, and that resulting quantitative definitions apply to all sections of the country irrespective of socio-economic conditions and current level of air quality. Allowable increments that can be added to air quality baselines are shown in table B-16.

Table B-16. Air Quality Increment Plan, allowable increments over baseline

Emission	Allowable increment by averaging time, $\mu g/m^3$ Annual	24-hour	3-hour
Particulate	10	30	–
Sulfur dioxide	15	100	300

2) Emission Limitation Plan

This plan indirectly prevents significant increases in emissions. The maximum allowable emissions for an Air Quality Control Region (AQCR) are defined for particulates as the product of the AQCR area and 3 tons of particulate matter per year per square mile or 120 percent of the baseline emission (whichever is greater). For sulfur dioxide, the allowable limit is the product of the AQCR area and 10 tons of sulfur dioxide per year per square mile or 120 percent of the baseline emissions (whichever is greater).

3) Local Definition Plan

This ensures that rate of deterioration is minimized. It requires the state to decide whether deterioration resulting from a particular source would be considered "significant".

4) Area Classification Plan

This plan is similar to the first mentioned Air Quality Increment Plan, except that it defines two air quality increments to be applied to appropriate areas of the state as shown in table B-17.

e. Indirect Sources

Indirect pollution sources are ancillary emissions expected from existing city expansion, new city creation, future power-plant development, and other industrial developments. Mobile source emissions are expected to be a major contributor of these sources. The EPA is to provide procedures for monitoring the NAAQS, which obligates the state to consider these indirect impacts in its new source review procedure.

Table B-17. Area Classification Plan, allowable deterioration increments

Emission	Zone	Allowable increment by averaging time, $\mu g/m^3$ Annual	24-hour	3-hour
Particulates	I	5	15	–
Sulfur dioxide	I	2	5	25
Particulates	II	10	30	–
Sulfur dioxide	II	15	100	300

2. Wyoming Standards

Wyoming adopted air pollution control regulations that consider both air quality standards and emission regulations equaling or exceeding the stringency of the National Ambient Air Quality Standards. The responsibility of the Wyoming Air Quality Division, Department of Environmental Quality, is to insure that the state standards are attained and maintained. The emission standards are listed in table B-18, and the ambient air quality standards are listed in table B-19.

Table B-18. Wyoming emission standards

Emission	Emission standard, pounds/MM Btu Existing source	New source (a)
Particulates		
MM Btu/hour fuel heat input (interpolate between values)		
10	0.6	0.10
10000	0.18	0.10
Nitrogen oxides		
Gas fried	0.23	0.20
Oil fried	0.46	0.30
Visible emissions	40% opacity	20% opacity

(a) After February 22, 1973.

Wyoming is divided into three Air Quality Control Regions as shown in figure B-36.

All Air Quality Control Regions within the U.S. are classified by priority as shown in table B-20, and those classifications as they apply to the Wyoming regions of interest are shown in table B-21.

chlorine, hydrogen fluoride, arsenic, beryllium, cadmium, manganese, nickel, vanadium, selenium, pesticides, radioactive substances, and aeroallergens; but standards have not been established to date.

d. Prevention of Significant Air Quality Deterioration

Prevention of air quality deterioration is an issue that has not been resolved since air quality deterioration has yet to be defined. Four plans are currently under consideration as described below.

1) Air Quality Increment Plan

This plan is based on the premise that significant deterioration can be defined as a finite increment in air quality and that resulting quantitative definitions apply to all sections of the country irrespective of cost-economic conditions and current level of air quality. Allowable increments that can be added to air quality baselines are shown in table B-16.

Table B-16. Air Quality Increment Plan, allowable increments over baseline

Emission	Allowable increment (in micrograms/cubic meter)		
	Annual	24-hour	3-hour
Particulate	10	30	–
Sulfur dioxide	10	100	300

2) Emission Limitation Plan.

This plan indirectly prevents significant increases in emissions. The maximum allowable emissions for an Air Quality Control Region (AQCR) are defined for particulates as the product of the AQCR area and 3 tons of particulates emitted per year per square mile, or 120 percent of the baseline emission (whichever is greater). For sulfur dioxide, the allowable limit is the product of the AQCR area and 10 tons of sulfur dioxide per year per square mile or 120 percent of the baseline emissions (whichever is greater).

3) Local Definition Plan

This ensures that rate of deterioration is minimized. It requires the state to decide whether deterioration resulting from a particular source would be considered "significant".

4) *Area Classification Plan*

This plan is similar to the first mentioned Air Quality Increment Plan, except that it defines four air quality increments to be applied to appropriate areas of the state as shown in table B-17.

e. Indirect Sources

Indirect pollution sources are auxiliary emissions expected from existing city expansion, new city creation, future power-plant development, and other industrial developments. Mobile source emissions are expected to be further

Table B-19. Wyoming ambient air quality standards

Emission	Standard by averaging time: Annual	Month	24-hour	8-hour	3-hour	1-hour	1/2-hour
Particulate, $\mu g/m^3$	60 G.M.	–	150[a]	–	–	–	–
COH/1000 feet	0.4	–	–	–	–	–	–
SO_2, $\mu g/m^2$	60	–	260[a]	–	1,300[a]	–	–
sulfation mg SO_3/100 cm^2/day	0.25	0.50	–	–	–	–	–
CO, mg/m^3	–	–	–	10[a]	–	40[a]	–
NO_x, $\mu g/m^3$	100 A.M.	–	–	–	–	–	–
HC, $\mu g/m^3$	–	–	–	–	160[a]	–	–
Oxidants, $\mu g/m^3$	–	–	–	–	–	160[a]	–
HF, Total, ppb	–	–	1	–	–	–	–
Forage – ppmw	25	–	–	–	–	–	–
gaseous – $\mu g/cm^2$	–	0.3	–	–	–	–	–
H_2S, $\mu g/m^3$	–	–	–	–	–	70	(2 times/ year)
						40	(2 times/ 5 days)

(a) Not to be exceeded more than once per year

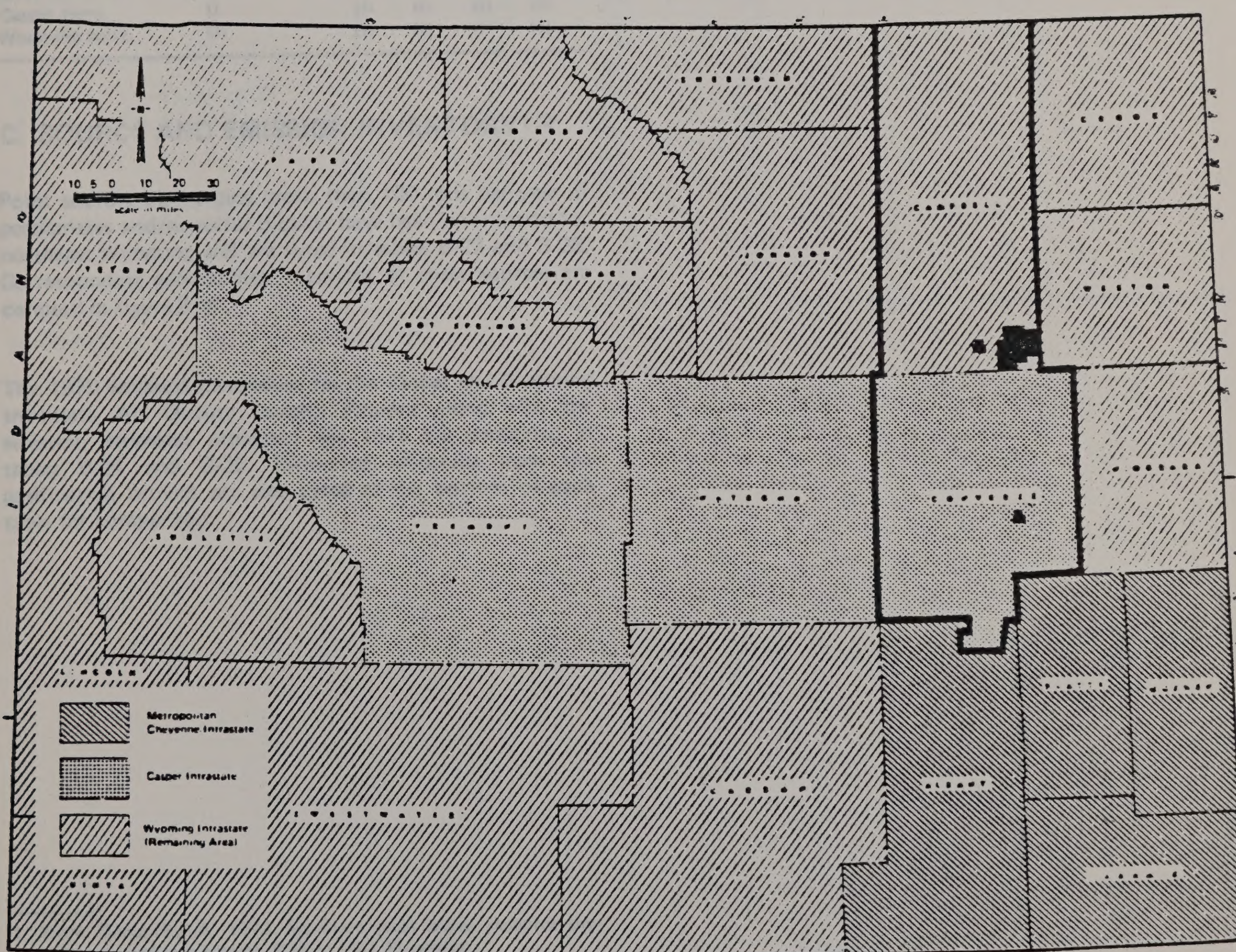

Figure B-36 Air Quality Control regions in Wyoming

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Table B-20. Federal pollutant classification system

Emission	Averaging time	Allowable ground-level concentration, µg/m³ (ppm) by priority classification: I (greater than)	II (from-to)	III (less than)
Particulates	Annual geometric mean	95	60-95	60
	24-hour maximum	325	150-325	150
Sulfur oxides	Annual arithmetic mean	100	60-100	60 (0.02)
	24-hour maximum	455 (0.17)	260-455	260 (0.10)
	3-hour maximum	–	-1300	1300 (0.50)
Carbon monoxide		(greater than or equal to)		(less than)
	8-hour maximum	14000 (12)		14000 (12)
	1-hour maximum	55000 (48)		55000 (48)
Nitrogen dioxide	Annual arithmetic mean		110 (0.06)	110 (0.06)
Photochemical oxidants	1-hour maximum			195 (0.10)

Table B-21. Air Quality Control Region classifications

Region	Classification by pollutant: Particulates	SO_2	CO	NO_x	$HC\text{-}O_x$
Cheyenne Intra	II	III	III	III	III
Casper Intra.	II	III	III	III	III
Wyoming Intra.	III	III	III	III	III

C. SOURCE AND EMISSION INVENTORY[1,2]

Point sources discharging more than 100 tons per year of particulates and/or sulfur dioxide have been inventoried for northeast Wyoming and are listed in tables B-22 and B-23. Corresponding geographical locations of these sources are denoted in figure B-37.

The 1970 emission inventories for the Casper and Wyoming Intrastate Air Quality Control Regions along with the emission estimates projected for 1975 are contained in tables B-24 and B-25. Estimated emissions from the gasification project are also listed at the bottom of each table for comparison.

1 Work Group/E.P.A. 1973. Northern great plains resource program atmospheric aspects. Region VIII. December.

2 Implementation Plan for Air Quality Control, State of Wyoming. January 1972.

Table B-22. Point sources emitting more than 100 tons per year of particulates and/or SO_2 in the Casper Intrastate Air Quality Control Region

		Particulate		SO^2	
Map reference number	Name and location	Emissions, tons/yr.	Allowable emissions, tons/yr.	Emissions, tons/yr.	Allowable emissions, tons/yr.
1.	Benton Clay *Mills*	150	35	0	(a)
2.	Great Lakes C. Co. *Casper*	221	69	257	(b)
3.	American Oil *Casper*	21	268	225	(b)
		21	268	225	(b)
		21	268	225	(b)
		172	197	464	(b)
		0	0	1040	(b)
4.	Texaco, Inc. *Evansville*	22	250	482	(b)
		23	250	505	(b)
		23	260	494	(b)
		24	260	529	(b)
		4	87	236	(b)
		2	49	118	(b)
		2	54	138	(b)
		2	76	3040	(b)
		2	66	171	(b)
		5	310	244	(b)
		3	81	200	(b)
		2	70	126	(b)
		4	124	226	(b)
		110	192	2100	(b)
		0	0	1081	(b)
5.	Little America Oil	124	227	1706	(b)
6.	PPL *Glenrock*	5020	1128	4770	(b)
		5850	1128	4920	(b)
		7580	2322	6240	(b)
		100	3344	3680	(b)
9.	Monolith Portland	62	127	3414	(b)
	Midwest	301	62	5	(a)
10.	Black Hills Power	474	44	75	(b)
	& Light *Wyodak*	315	38	63	(b)
		729	269	580	(b)

(a) Indicates emission regulations not applicable.

(b) Indicates that there are no emission regulations.

Table B-23. Point sources emitting more than 100 tons per year of particulates and/or SO_2 in the Wyoming Intrastate Air Quality Control Region

Map reference number	Name and location	Particulate: Emissions, tons/yr.	Particulate: Allowable emissions, tons/yr.	SO^2: Emissions, tons/yr.	SO^2: Allowable emissions, tons/yr.
7.	Montana-Dakota Utilities *Sheridan*	1729	102	500	(b)
		132	742	38	(b)
8.	Big Horn Gypsum *Big Horn*	244	109	0	(a)
		106	109	0	(a)
11.	Con Agra *Hwy 87 & 14*	100	23	0	(a)
12.	Wyodak Resource Development *Wyodak*	647	45	0	(a)
13.	Fed. Bentonite *Crook*	382	121	1	(b)
14.	Inter Minerals & Chemicals *Colony*	1080	131	0	(a)
15.	American Colloid *Upton*	1013	158	0	(a)
		176	157	0	(b)
16.	Fed. Bentonite *Upton*	442	75	0	(b)
		303	75	0	(b)
17.	Baroid Division *Osage*	291	112	0	(a)
18.	Black Hills Power & Light *Osage*	126	49	290	(b)
		125	51	290	(b)
		125	51	289	(b)
		105	3	2	(b)
19.	Tesoro Petr. Co. *Newcastle*	252	155	288	(b)
		79	64	109	(b)

(a) Indicates emission regulations not applicable.

(b) Indicates that there are no emission regulations.

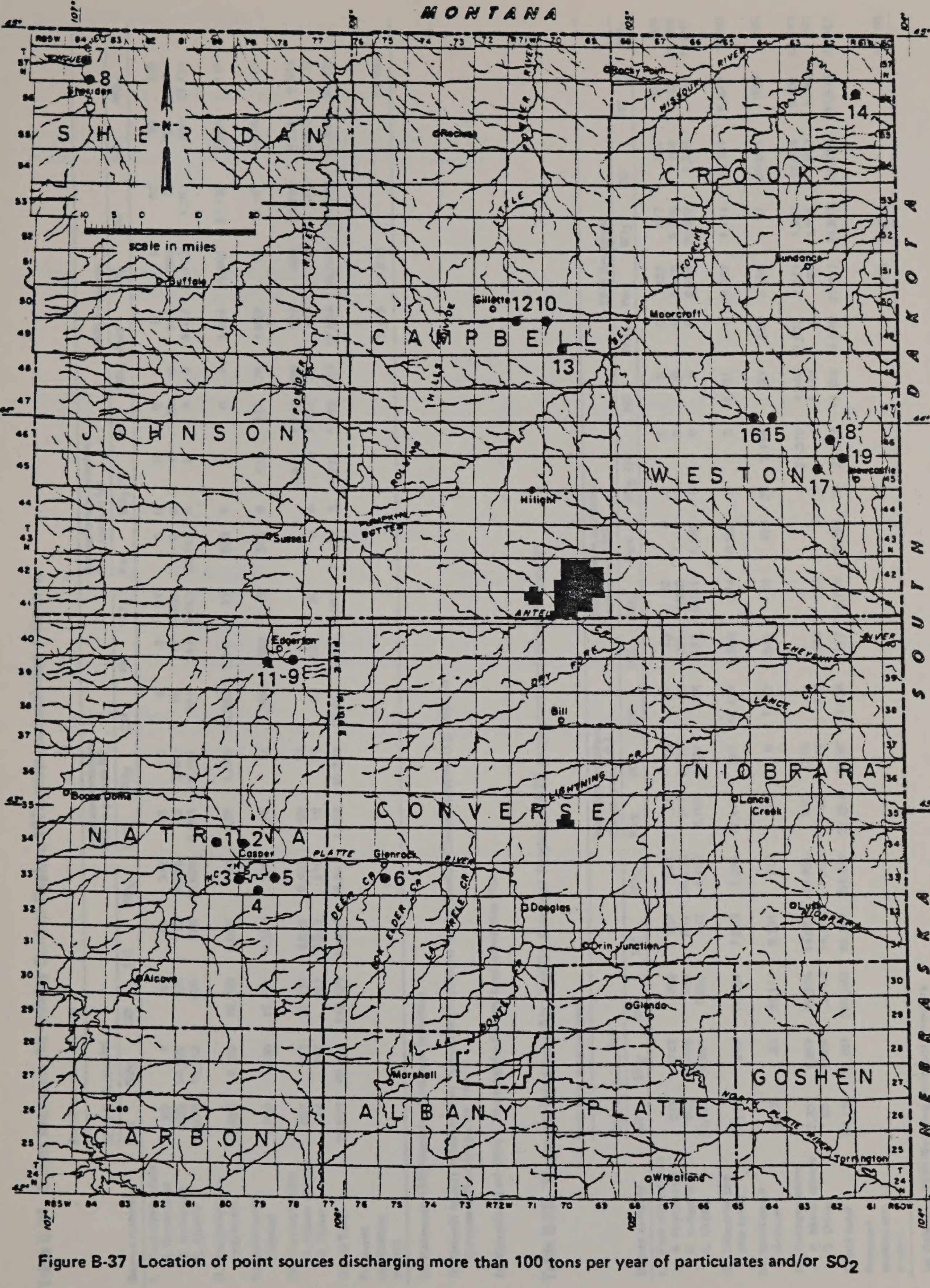

Figure B-37 Location of point sources discharging more than 100 tons per year of particulates and/or SO_2

Table B-24. Casper Intrastate Air Quality Control Region, 1975 projected emission estimates.

Emissions, tons per year

Source category	1970 Emissions[a]					Increased emissions due to growth (b)					Reductions in emissions from control (c)					1975 emissions				
	Part	SO_2	CO	HC	NO_x	Part	SO_2	CO	HC	NO_x	Part	SO_2	CO	HC	NO_x	Part	SO_2	CO	HC	NO_x
I. Fuel combustion																				
A. Residential	82	1	87	34	318	5	0	6	2	21	0	0	0	0	0	87	1	93	36	339
B. Industrial	303	14,262	59	319	4,826	73	3,423	14	77	1,158	0	0	0	198	0	374	17,685	72	193	5,984
C. Utility	20,076	19,012	926	276	16,678	6,083	5,761	281	84	5,053	20,142	0	0	0	0	6,017	24,773	1,207	360	21,731
II. Industrial process losses	3,493	4,355	70,750	6,008	93	839	1,045	16,980	1,442	22	650	0	0	0	0	3,694	5,400	87,730	7,450	115
III. Solid waste disposal	1,700	30	17,422	4,586	120	116	2	1,150	303	8	310	6	431	214	25	1,562	26	18,141	4,675	103
IV. Transportation																				
A. Motor vehicle	687	331	32,634	4,838	6,402	150	72		--		...		8,844	1,703	499	837	403	23,790	3,135	5,903
B. Other	104	211	551	5,572	210	10	20	52	529	20	0	0	0	3,031	0	114	231	603	3,050	230
Grand Total	26,510	38,202	122,429	21,633	28,647	7,276	10,323	18,483	2,437	6,282	21,102	6	9,275	5,166	524	12,684	48,519	131,636	18,904	34,405
Proposed gasification project																1,375	12,811		--	13,700

(a) Reference 1970 Wyoming Emissions Inventory.

(b) Growth factors obtained from "Economic Projections for Air Quality Control Regions, U.S. Dept. of Commerce Publication, pg. 140.

(c) Compliance schedule – Wyoming Air Quality Implementation Plan.

Table B-25. Wyoming Intrastate Air Quality Control Region, 1975 projected emissions estimates.

Emissions, tons per year

Source category	1970 Emissions (a)					Increased emissions due to growth (b)					Reductions in emissions from control (c)					1975 Emissions				
	Part	SO_2	CO	HC	NO_x	Part	SO_3	CO	HC	NO_x	Part	SO_2	CO	HC	NO_x	Part	SO_2	CO	HC	NO_x
I. Fuel combustion																				
A. Residential	318	213	709	194	627	21	14	47	13	42	0	0	0	0	0	333	227	756	207	669
B. Industrial	903	5,466	152	861	16,620	217	1,312	36	207	3,989	0	0	0	0	0	1,120	6,778	188	1,068	20,609
C. Utility	13,727	15,581	1,002	403	4,159	4,159	4,721	304	122	6,951	10,982	0	0	0	0	6,904	20,302	1,306	525	29,892
II. Industrial process losses	72,806	944	76,767	7,873	2,265	17,472	227	18,424	1,890	544	50,961	0	0	4,881	0	39,312	1,171	95,181	4,882	2,809
III. Solid waste disposal	3,365	82	30,177	8,201	274	222	5	1,992	541	18	424	36	2,144	757	137	3,160	51	30,025	7,985	155
IV. Transportation.																				
A. Motor vehicle	2,333	1,097	89,925	14,051	19,895	510	240		--	--		...	24,370	4,946	1,552	2,841	1,337	65,555	9,105	18,343
B. Other	694	1,804	2,454	14,144	1,995	66	171	233	1,344	190	0	0	0	7,744	0	760	1,975	2,687	7,744	2,185
Grand total	94,139	25,187	201,186	45,727	64,617	22,657	6,690	21,036	4,117	11,734	62,367	36	26,514	18,328	1,689	31,437	31,841	195,708	31,516	74,662
Proposed gasification project																1,375	12,811			13,700

(a) Reference 1970 Wyoming Emissions Inventory.

(b) Growth factors obtained from "Economic Projections for Air Quality Regions", U.S. Dept. of Commerce Publication, pg. 140.

(c) Compliance Schedule – Wyoming Air Quality Implementation Plan

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D. AIR QUALITY DATA

1. State and Federal Summaries

The 1970 air quality data summaries for the Wyoming and Casper Intrastate Air Quality Control Regions are presented in tables B-26 and B-27.

Table B-26. Air quality data summary for Wyoming Intrastate Air Quality Control Region No. 243.

Emission	Sampling method	Station identification	Annual average, $\mu g/m^3$	Maximum 24 hour average, $\mu g/m^3$	Number of samples	Sampling period
Suspended particulate	Hi-Vol	243-2 Grand Teton Ntl Park	10 G.M.	39	26	1970
		243-3 Yellowstone Ntl Park	8 G.M.	33	24	1970
	Estimated[a]	–	–	260[e]	–	–
Sulfur oxides	Bubbler	243.3 Yellowstone Ntl Park	4 G.M.	23	12	July-Dec. 1970
	Estimated[a]	–	–	260	–	–
Nitrogen oxides	Estimated[b]	–	100 G.M.	–	–	–
Photo chemical oxidants	Estimated[b]	–	–	160[c]	–	–
Carbon monoxide	Estimated[b]	–	–	10,000[d]	–	–

(a) Estimating technique used was the Miller-Holzworth point source model documented in April 7, 1971. Fed. Reg.

(b) Estimation basis is August 14, 1971, Federal Register, pg. 15488, where it states that any region not having an urban place population greater than 200,000 shall be classified priority III, i.e., having an air quality below the second standard.

(c) Maximum 1 hour avg.

(d) Maximum 8 hour avg.

(e) This value exceeds the primary ambient air quality standard reflecting the need for much source oriented sampling in this region

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Table B-27. Air quality data summary for Casper Intrastate Air Quality Control Region No. 241.

Emission	Sampling method	Station identification	Annual average, $\mu g/m^3$	Maximum 24 hour average, $\mu g/m^3$	Number of samples	Sampling period
Suspended particulate	Hi-Vol	241.1 (Casper	58 G.M.	218	26	1970
		Mills 1	–	213[a]	7	1 week 1969
		Mills 2	–	289[a]	7	
		Mills 3	–	248[a]	7	
		Mills 4	–	274[a]	7	
		Mills 5	–	235[a]	7	
	Estimated[b]	–	–	150	–	
Sulfur oxides	Bubbler	241.1 (Casper)	10 G.M.	29	25	1970
	Estimated[b]	–	–	260	–	–
Nitrogen oxides	Estimated[c]	–	100 G.M.	–	–	–
Photochemical oxidants	Estimated[c]	–	–	–160[d]	–	–
Carbon monoxide	Estimated[c]	–	–	10,000[e]	–	–

(a) Reflects source-oriented type sampling.

(b) Estimating technique used was the Miller-Holzworth point source model. April 7, 1971, Federal Register.

(c) Estimation basis is August 14, 1971, Federal Register, pg. 15488, where it states that any region not having an urban place population greater than 200,000 shall be classified priority III, i.e., having an air quality below the secondary standard.

(d) Maximum 1 hour avg.

(e) Maximum 8 hour avg.

Summaries from the Casper site of the National Air Surveillance Network (NASN) provide information on the sulfur dioxide, particulate and NO_x levels for the years 1967 through 1972. Particulate samples were analyzed during 1968 and 1969 to determine their levels of trace elements. Complete NASN data are listed in table B-28 and sample collection and analysis methods are listed below. Column 4 of table B-28 uses the following numbers to indicate method:

1. Hi-Vol/gravimetric (24 hr. sample)
2. Hi-Vol/turbidimetric (24 hr. sample)
3. Hi-Vol/specific ion electrode (24 hr. sample)
4. Hi-Vol/proportional counter (24 hr. sample) (pico-curies/cu. meter)
5. Hi-Vol/colorimetric (24 hr. sample)
6. Hi-Vol/reduction diazo coupling (24 hr. sample)
7. Hi-Vol/emission spectra
8. Hi-Vol/Willard Winter. specific ion (24 hr. sample)
9. Hi-Vol/benzene extraction – SOXHLET (24 hr. sample)
10. Hi-Vol/emission spectra – muffle furnace (24 hr. sample)
11. Hi-Vol/emission spectra – low temp. ash (24 hr. sample)
12. Hi-Vol/2-4 xylenol (24 hr. sample)
13. Hi-Vol/sodium phenolate (24 hr. sample)
14. Gas Bubbler/Jacobs-Hoshheiser (100 ml tube & frit) (24 hr. sample)
15. Gas Bubbler/West Gaeke sulfamic acid (24 hr. sample)
16. Gas Bubbler/sodium phenolate (24 hr. sample)
17. Tape sampler transmittance (2 hr. sample) CoHS/1000 linear feet.
18. Hi-Vol/Nessler (24 hr. sample)
19. Lead candle gravimetric (1 month sample, mg SO_3/100 sq. cm/day)

Table B-28. NASN particulate and trace element data for Casper, Wyoming.

Site	Emission	Year	Sampling-analyzing method (keyed on page B-43)	Number of samples	Extremes, $\mu g/m^3$ Min obs	Extremes, $\mu g/m^3$ Max obs	Quarterly means, $\mu g/m^3$ 1	2	3	4	Annual mean, $\mu g/m^3$	Stand. deviation, $\mu g/m^3$	Standards, $\mu g/m^3$ Prime	Standards, $\mu g/m^3$ Second	No. of observations greater than standard Prime	Second
Casper	Total suspended particulates	1972	1	29	11	166	48	47	79	80	61	1.98	260 (24 hr) 75 (ann)	150 (24 hr) 60 (ann)	0	2
		1971	1	26	13	255	44	71	97	120	77	1.94			1	3
		1970	1	26	23	128	44	70	84	39	57	1.62			0	0
		1969	1	25							61	1.71				
		1968	1	26	19	126	55	52	68	45	55	1.59			0	0
		1967	1	26	22	125					55	1.55				
	SO_2	6/72-6/73	15	64	0	16	4	2	2	2	2	3	365 (24 hr) 80 (ann)	260 (24 hr) 60 (ann)	0	0
		1972	15	28	3	16	3	4	4	9	5	4			0	
		1970	15	25	3	27	13	11	9	5	9	8			0	0
		1969	15	25	5	74	21	7	8	20	14	16				
		1968	15	26	3	28	11	8	10	9	9	5				
		1967	15	25	4	113	43	12	17	28	25	27				
	NO_x	1972	14	26	3	121	28	65	34	46	43	26	100 (ann)	100 (ann)		
		1971	14	24	15	247	51	39	112	70	68	60				
		1970	14	25	20	267	43	78	37	34	48	47				
		1969	14	26	23	111	47	49	54	35	47	20				
		1968	14	22	30	116	58	58	57	66	60	21				
Casper	Beryllium	1968	11	26	0	0.0008	24 samples below minimum dectectable concentration									
		1969	11				0	0	0	0						
	Cadmium	1968	11	26	0	0	26 samples below minimum detectable concentration									
		1969	11				0	0	0	0	---					
	Chromium	1968	11	26	0	0.021	22 samples below minimum detectable concentration									
		1969	11				0	0	0	0	--					
	Cobalt	1968	11	26	0	0	26 samples below minimum detectable concentration									
		1969	11				0	0	0	0	---					
	Copper	1698	11	26	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.000				
		1969	11				0.05	0.22	0.18	0.07	0.13					
	Iron	1968	11	26	0.7	3.6	0.7	0.7	0.7	0.7	0.71	0.71				
		1969	11				0.2	1.2	1.2	1.0	0.9					
	Lead	1968	11	26	0.04	0.71	0.17	0.16	0.17	0.26	0.19	1.4				
		1969	11				0.18	0.73	0.62	0.54	0.52					
	Manganese	1968	11	26	0	0	26 samples below minimum detectable concentration									
		1969	11				0	0	0	0	---					
	Nickel	1968	11	26	0	0.014	25 samples below minimum detectable concentration									
		1969	11				0	0	0	0	--					
	Tin	1968	11	26	0	0	26 samples below minimum detectable concentration									
		1969	11				0	0	0	0	--					

(continued next page)

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Table B-28 (continued)

Site	Emission	Year	Sampling-analyzing method (keyed on page B70)	Number of samples	Extremes, $\mu g/m^3$ Min obs	Max obs	Quarterly means, $\mu g/m^3$ 1	2	3	4	Annual mean, $\mu g/m^3$	Stand. deviation, $\mu g/m^3$	Standards, $\mu g/m^3$ Prime	Second	No. of observations greater than standard Prime	Second
	Titanium	1968	11	26	0	0	26 samples below minimum detectable concentration									
		1969	11				0	0	0	0	--					
	Samarium	1968	11	26	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00				
	Strontium	1968	11	26	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.1				
	Vanadium	1968	11	26	0	0	26 samples below minimujm detectable concentration									
		1969	11				0	0	0.009	0	--					
	Yttrium	1968	11	26	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000				
	Flourkde ion	1970	3	26	0.02	0.11	0.09	0.09	0.02	0.02	0.06	0.03				
		1969	3	25	0.02	0.06	0.03	0.02	0.02	0.02	0.03	0.01				
		1968	3	26	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00				
		1967	3	26	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00				
	Ammonium ion	1970	13	26	0.02	0.30	0.13	0.18	0.4	0.4	0.10	0.08				
		1969	13	25	0.02	0,70	0.5	17.	0.33	0.29	0.19	0.21				
		1968	13	26	0.10	0.20	0.17	0.10	0.11	0.12	0.13	0.05				
		1967	13	25	0.02	0.30	0.11	0.7	0.9	0.10	0.09	0.06				
	Nitrate ion	1970	6	26	0.10	1.30	0.31	0.57	0.80	0.33	0.51	0.34				
		1969	6	25	0.10	2.30	0.70	0.70	0.94	0.45	0.71	0.49				
		1968	6	26	0.30	1.40	0.60	0.70	0.63	0.60	0.63	0.29				
		1967	6		0.30	1.10	0.42	0.51	0.76	0.45	0.54	0.20				
	Sulfate ion	1970	5	26	2.4	6.9	4.6	5.0	5.4	3.8	4.7	1.2				
		1969	5	25	2.6	12.7	7.1	3.3	5.6	5.5	5.5	2.3				
		1968	5	26	2.1	8.2	3.1	3.0	5.0	3.2	3.6	1.6				
		1969	5	26	1.4	6.3	3.2	3.1	3.0	1.9	2.8	1.1				
	Ammonia	1969	16	25	28.	114.	52	74	41	43	52	20				
		1968	16	25	28	137	44	77	63	47	58	25				
		1967	16	25	10	71	25	33	43	44	36	14				
Ranch 50 mi. E. of Casper	Total suspended particulates	1/73 6/73	1	25	44	77	19	221	--	--	60	1.70	260 (24 hr) 75 (ann)	150 (24 hr) 60 (ann)		

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2. Specific Air Quality Data

A comparison of 1972 Casper and Gillette particulate levels to secondary National Ambient Air Quality Standards is presented in table B-29.

Table B-29. 1972 Particulate comparison to secondary NAAQS

Location	Particulates observed, $\mu g/m^3$ Maximum 24-hour	Annual	Secondary NAAQS, $\mu g/m^3$ Maximum 24-hour	Annual
Casper	166	60	150	60
Gillette	190	73	150	60

The following data was obtained from the State of Wyoming Department of Environmental Quality from station locations shown in figure B-1.

The HI-VOL site, established at Burk's Ranch (table B-30) on January 28, 1973, is situated approximately 8 miles east of the Dave Johnston Power Plant. This station is not a true "background station", due to effects from adjacent power plant emissions, but the data are considered representative of the area.

Table B-30. Particulate measurements at Burk's Ranch

Month	Year	Particulate concentration, $\mu g/m^3$ Range	Geometric mean
Jan.	1973	35	35
Feb		31-143	51
Mar.		19-65	39
Apr.		40-98	68
May		31-221	100
June		46-80	64
July		60-121	83
Aug.		44-76	58
Sept.		22-58	36
Oct.		35-130	71
Nov.		38-94	51
Dec.		22-161	55
Jan.	1974	46-98	77
Feb.		34-64	47

The Stoddard Ranch site, established 11/14/73, is situated next to the ranch house some 250 yards east of highway 59, and is considered a background station for gathering particulate information. Data from this station are presented in table B-31.

Table B-31. Particulate measurements at Stoddard Ranch

Month	Year	Particulate concentration, $\mu g/m^3$ Range	Geometric mean
Nov.	1973	14	14
Dec.	1973	7-19	11
Jan.	1974	9-29	16

The Reno Junction site, established February 9, 1973, is located behind a trailer 150 yards east of highway 59. This station is also considered a background station for particulate emissions. Only data for February, 1974 are available, indicating a range of 43 to 130 $\mu g/m^3$ and a geometric mean of 74 $\mu g/m^3$.

The HI-VOL site established November 24, 1973 at Moorcroft is located on the east side of town in a trailer court on top of a hill. The monitor is directly across from a high school and could pick up intown particulates. The data from this station are presented in table B-32.

Table B-32. Particulate measurements at Moorcroft

Month	Year	Particulate concentration, $\mu g/m^3$ Range	Geometric mean
Nov.	1973	68	68
Dec.	1973	15-58	28
Jan.	1974	24-45	30
Feb.	1974	60-87	72

Air quality monitoring at the south site, was started in mid-January, 1974. This monitoring station, installed adjacent to the meteorological stations, contains a Bendix FID gas chromatograph for detecting carbon monoxide (CO), methane (CH_4) and total hydrocarbons (THC); a Bendix gas chromatograph for sulfur dioxide (SO_2), hydrogen sulfide (H_2S) and total sulfur (TS); a TECO chemiluminescent unit for nitric oxide (NO), nitrogen dioxide (NO_2) and total nitrogen oxides (NO_x); a Bendix chemiluminescent ozone (O_3) monitor; and a HI-VOL unit for particulate sampling. Preliminary data from continuous measurements are summarized below in table B-33.

Table B-33. Preliminary background emission concentrations observed at south plant site (January, 1974)

Emission	Average for the mo. $\mu g/m^3$	Range of hourly avg. $\mu g/m^3$
Nitrogen dioxide (NO_2)	9	<4 - 80
Nitric oxide (NO)	6	<6 - 80
Total nitrogen oxides (NO_x)	15	<10 - 160
Ozone (O_3)	75	20 - 100
Sulfur dioxide (SO_2)	<10	<10
Hydrogen sulfide (H_2S)	<10	<10
Total sulfur (TS)	<10	<10
Particulates	8.5	4 - 16 (24-hr. values)
Methane (CH_4)	920	850 - 1000
Non-methane hydrocarbons	250	230 - 400
Carbon monoxide (CO)	3000	3000

The above values, although acquired over a short time period, are realistic in terms of a rural area. Continued monitoring at the site should give a valid pollutant baseline for the area. During this period, the instruments indicated a substantial increase in sulfur and nitrogen oxides and decrease in ozone during a southwest wind. These changes could be a result of transport from Glenrock and/or Casper. These values are indicated in table B-34.

Table B-34. Transitory emission concentrations observed at south plant site (January 11, 1974).

Emission	Transient concentrations, $\mu g/m^3$
Nitrogen dioxide	120
Nitric oxide	90
Total nitrogen oxides	200
Ozone	40
Sulfur dioxide	97
Hydrogen sulfide	<10
Total sulfur	100

The analyzer chart records for January 11, 1974 are shown in figure B-38 and indicate the concentration levels of each emission during the southwest wind incident. It is noted that with the simultaneous occurrence of the NO and NO_2 peaks there is a concurrent decrease in ozone concentrations.

On January 17, 1974, significant levels of nitrogen oxides were recorded, (figure B-39) but no sulfur components were detected. It is of special interest to note that during the night, NO_2 peaks were accompanied by decreases in ozone concentrations, but that nitric oxide was not detected. During mid-day, NO_2 peaks were accompanied by NO peaks, and dips in ozone concentration. This indicates that photo-dissociation of NO_2 by sunlight to NO is occurring during the day.

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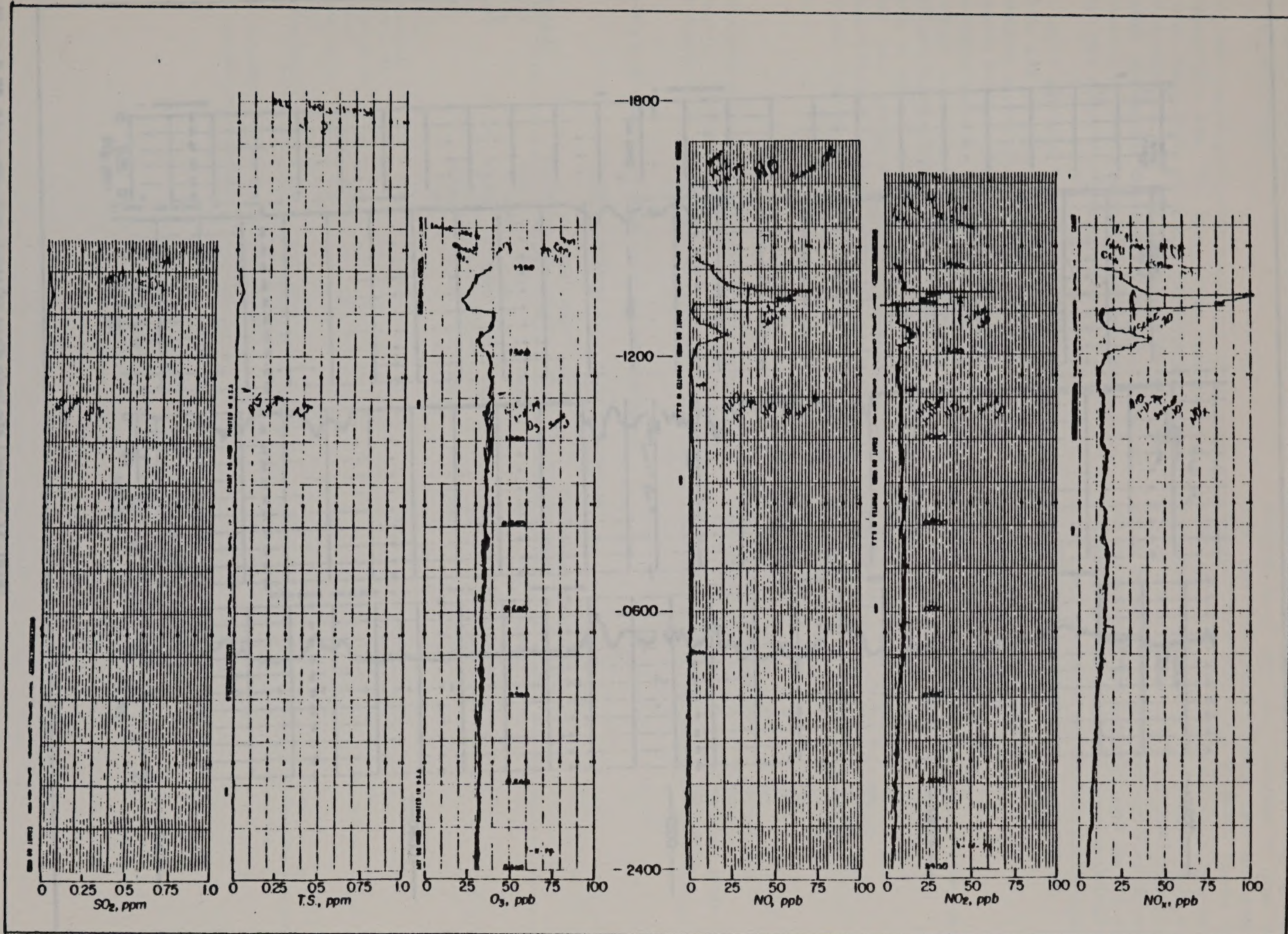

Figure B-38 Air quality data charts for south plant site (January 11, 1974)

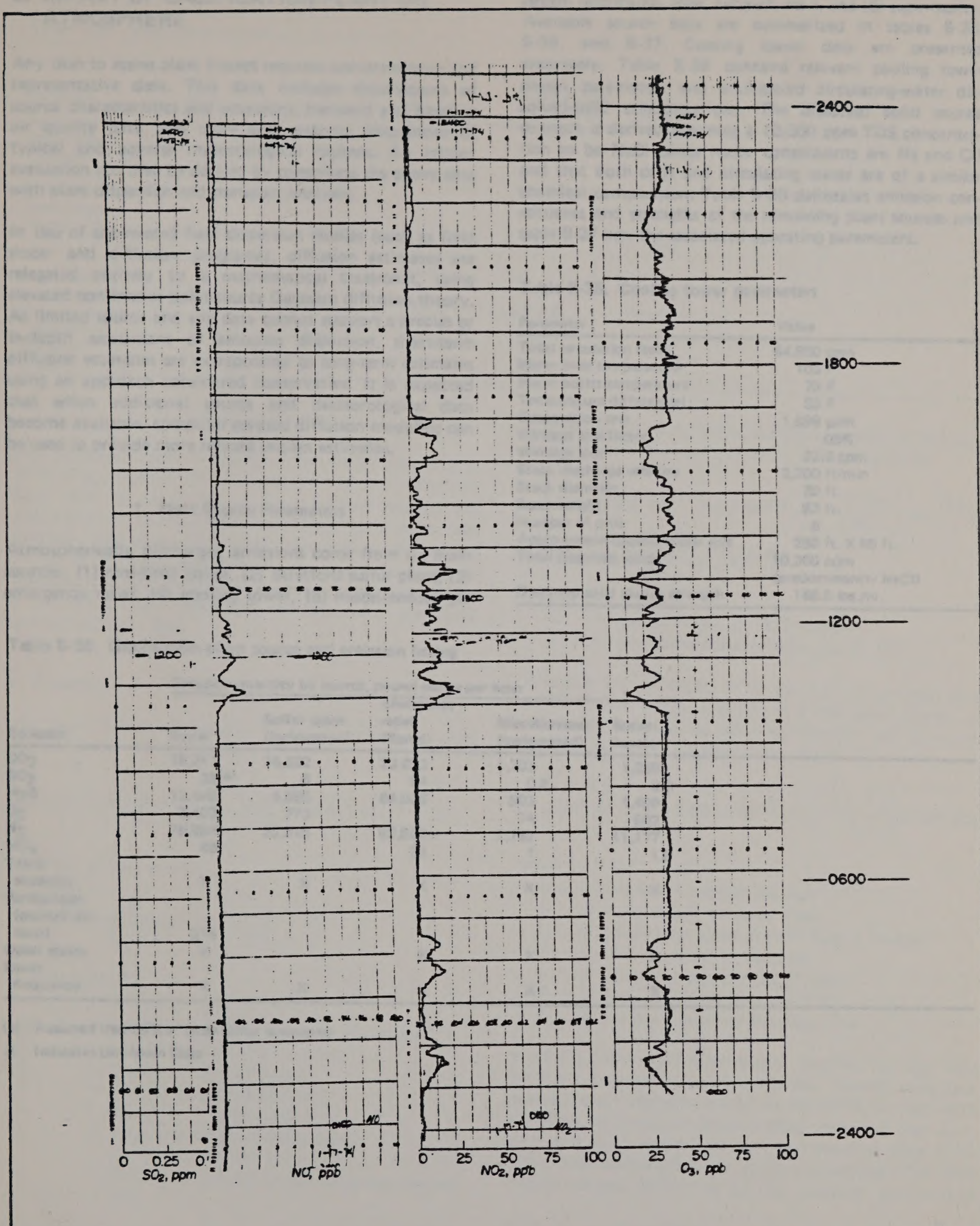

Figure B-39 Air quality data charts for south plant site (January 17, 1974)

E. IMPACT OF GASIFICATION PLANT ON ATMOSPHERE

Any plan to assess plant impact requires comprehensive and representative data. This data includes descriptions of source characteristics and emissions, transient and baseline air quality data, and daily and seasonal frequencies of typical and adverse meteorological regimes. An impact evaluation can then be derived by combining the above data with plant dispersion and transport analyses.

In lieu of site-related field dispersion studies (such as field tracer and diffusion programs), diffusion estimates are relegated entirely to a mathematical treatment, using elevated continuous point-source Gaussian diffusion theory. As limited source and site data cannot support a precise or in-depth assessment of emission dispersion, short-term diffusion estimates are extrapolated to long-term estimates using an approach considered conservative. It is expected that when additional source and meteorological data become available, computer assisted diffusion modeling can be used to provide more refined impact estimates.

1. Plant Source Parameters

Atmospherically discharged emissions come from six main sources: (1) coal-fired boiler, (2) Stretford sulfur plant, (3) emergency relief, (4) cooling tower, (5) miscellaneous gas stream (expansion, lock, exhaust, etc.), and (6) superheater. Available source data are summarized in tables B-35, B-36, and B-37. Cooling tower data are presented separately. Table B-35 contains relevant cooling tower design parameters and anticipated circulating-water dissolved-solid concentrations. The dissolved solid source strength is derived assuming a 10,000 ppm TDS concentration to be NaCl (since major constituents are Na and Cl) and that both drift and circulating water are of a similar chemical composition. Table B-36 delineates emission constituents and strengths of the remaining plant sources and table B-37 lists the associated operating parameters.

Table B-35. Cooling tower parameters

Parameter	Value
Total circulation rate	64,960 gpm
Water inlet temperature	105 F
Water outlet temperature	75 F
Temperature differential	30 F
Evaporation rate	1,898 gpm
Windage loss factor	.05%
Windage loss	32.5 gpm
Stack discharge velocity	2,200 ft/min
Stack diameter	30 ft.
Stack height	63 ft.
Number of cells	6
Approximate cooling tower size	250 ft. X 80 ft.
Total dissolved solids	10,000 ppm (predominantly NaCl)
Dissolved solid source strength	166.5 lbs./hr.

Table B-36. Gasification plant source and emission listing

Emission	Emission quantity by source, pound moles per hour: Boiler	Sulfur plant (incinerated)	Emergency relief (flared)	Miscellaneous (incinerated)	Superheater
CO_2	15,317	36,602	23,673	1,703	1,268
SO_2	35[a]	6	54	0.9	0.8
H_2O	12,448	4,595	64,036	803	1,400
O_2	3,402	773		74	502
N_2	76,854	20,315	82,862	2,732	11,177
NO_x	48		85	1	1.9
Trace elements	X	X	X	X	X
Particulates (pounds per hour)	314				
Upset states	X		X	X	X
Upset frequency	X	X	X	X	X

(a) Assumed that 95% of total sulfur is emitted

X Indicates Unknown Data

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Table B-37. Gasification plant source parameters

Parameter	Boiler	Sulfur plant (incinerated)	Emergency relief (flared)	Miscellaneous (incinerated)	Super-heater
Stack height (m)	91	61	61	61	61
Stack exhaust velocity (m/sec)	27.4	27.4	91.4	27.4	27.4
Inside stack diameter (m)	5.34	4.06	2.13	1.18	1.64
Stack exhaust temp. (°K)	450	450	1811 ignition 311 Pre-ignition	450	450
Total source strength	108,093	62,294	170,710	5313.9	14,933.8
Exhaust volume (m^3/sec)	615	355	421	30	85
Operation	Cont.	Cont.	Infrequent	Cont.	Cont.

2. Dispersion Analysis

The dispersion analysis described here yields estimates of both long-and short-term emission ground-level concentrations that can be related to environmental impacts and applicable air quality standards. The study itself uses semi-empirical equations derived from actual field experiments as expressed in terms of continuous point-source Gaussian diffusion theory.[1] These relationships are capable of providing "best" dispersion estimates when used with appropriate input data.

a. Equations

The basic diffusion equations describing lateral and axial ground-level concentrations are:

$$x(x,y,H) = \frac{Q}{\pi \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

when $\sigma_z < 0.8L$ and by

$$x(x,y) = \frac{Q}{\sqrt{2\pi}\,\sigma_y L \bar{u}} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

when $\sigma_z \geq 0.8L$

x(x,y) = emission concentration at (x,y), (gm/m^3)
Q = source emission rate, (gm/sec)
$\bar{u}$ = mean wind speed, (m/sec)
H = effective source height, (m)
L = mixing layer height, (m)
y = crosswind standard deviation of concentration, (m)
z = vertical standard deviation of concentration, (m)

Concentrations determined from the above equations are respresentative of time averages corresponding to values of σ_y and σz, as related to wind field fluctuations, stability and downwind distance from the source. The best documented values of σ_y and σ_z are representative of 10-minute concentration averages and can be approximated by:

$$\sigma_z = 178\ (0.69)^S\ (x/1000)^{0.9} \left[1 + \frac{0.65x}{1000}\right] \exp\left[\frac{3.6}{s} - 1.2\right]$$

$$\sigma_y = 312\ (0.69)^S\ (x/1000)^{0.9}$$

where:
s = stability class, (A=1, B=2, etc.)
x = downwind distance from source, (m)

Effective source height H is the sum of physical stack height h and plume rise Δh. A conservative plume rise expression, considering both momentum and buoyancy factors, is given by the Holland equation:

$$\Delta h = \frac{V_s D}{\bar{u}} \left[1.5 + 2.68 \times 10^{-3}\ pd \left(\frac{T_s - T_a}{T_s}\right)\right] (1.28 - 0.08s)$$

where:
V_s = stack exit velocity, (m/sec)
p = atmospheric pressure, (mb)
u = mean wind speed at stack height, (m/sec)
d = inside stack diameter, (m)
s = stability class, (A=1, B=2, etc.)
T_a = ambient air temperature, (°K)
T_s = stack emission temperature (°K)

Normally, with definitive source engineering data and adequate meteorological information, average long-term concentration estimates would be derived from short-term diffusion estimates by incorporating frequency and duration data from site-related daily and seasonal wind variations, and temperature and stability structures. The final output would consist of specific emission ground-level

[1] Turner, D. B. 1971. Workbook of atmospheric dispersion estimates U.S. Environmental Protection Agency, ESSA. United States Atomic Energy Commission. 1968. Meteorology and

concentration isograms estimated for hourly, daily, monthly and yearly time intervals. Generally, concentration isopleths are distorted in the direction of predominant winds.

In the absence of such meteorological data, long-term estimates are extrapolated from short-term estimates using the following semi-empirical power law expression:

where:

$$\chi_k = \chi_p \left(\frac{t_p}{t_k}\right)^q$$

χ_k = concentration at time t_k
χ_p = concentration at time t_p
t_k = desired long-term averaging time
t_p = short-term averaging time
q = exponent ranging from 0.2 to 0.5

Extending the diffusion equation's 10-minute averaging interval to periods consistent with federal and state Ambient Air Quality Standards, results in the reduction factors summarized in table B-38 below.

Table B-38. Extrapolated concentration reduction factors

Averaging time	Reduction factors q = 0.2	q = 0.5
10 minutes	1.00	1.00
30 minutes	.80	.58
1 hour	.70	.41
3 hours	.56	.24
8 hours	.46	.14
24 hours	.37	.08
Annual	.11	.005

b. Model Assumptions and Accuracy

The equations described in the preceding section contain a number of inherent assumptions; and the results obtained must be tempered with these in view. The following assumptions apply to the 10-minute average dispersion estimates found in the next section:

- Complete reflection of the plume at the surface is assumed, so surface absorptions and reactions, washout, fallout and such are ignored. This results in downwind concentration over-estimates.
- Lifetime of pollutants is considered "infinite," resulting again in downwind over-estimates.
- A Gaussian distribution of plume concentrations is assumed in the plane normal to plume trajectory. This means that each molecule moves randomly in time and space independently of other molecules. The probability of finding a given molecule at a given point at a particular time is then described by the bivariate normal distribution.
- Source emissions are assumed constant and continuous during the averaging time. This is true of all plant emissions.
- Wind speed and direction is assumed to be relatively constant.
- Dispersion layer stability is assumed to be homogenous.
- The vertical wind shear is assumed to be zero. Ground level overestimates will result if surface wind data are employed for elevated sources.
- A flat terrain is assumed.

In addition to the above influences on accuracy, estimated values of the vertical standard deviations of plume concentration, σ_z may contain significant errors far from the source under extremes in stability conditions. Values may be accurate within a factor of 2 under the following conditions:

- All stabilities for travel distances within 1,000 feet of the source.
- Neutral and moderately unstable conditions for distances within a few miles.
- Unstable conditions in the first 3,000 feet above the surface with marked inversion aloft for distances within 6 miles or more.

Uncertainties in the lateral standard deviations, σ_y, are typically less than σ_z, except for indefinite wind fields. Axial ground-level concentrations for the above three conditions should be correct within a factor of 3, including errors in σ_y and $\bar{u}$. One of the more critical parameters used in calculating ground-level concentrations is the effective source height H. The Holland equation was selected because it underestimates plume rise, resulting in concentration overestimates, providing a "safety margin." Estimated effective source heights, which are computed in the next section in excess of 914 meters were truncated at 914 meters as a secondary conservative measure. A q value of 0.2 was also selected for the long-term surface concentration extrapolations of the 10-minute diffusion estimates. This provides the most conservative set of reduction factors.

In summary, concentration estimates using the preceding equations and factors are intended to be conservative.

c. Dispersion Estimates

The equations and source emission data described in preceding sections are now employed to estimate specific source emission ground-level concentrations. These estimates are done under various meteorological conditions and in time frames consistent with state and federal air quality standards. It is assumed throughout this analysis that emission strengths for continuous sources are constant in time.

1) Boiler, Sulfur Plant, Emergency Relief, Miscellaneous Gas Stream, Superheater

Effective source heights for the boiler, sulfur plant, emergency relief flares, miscellaneous gas stream, and superheater are calculated together with their associated

ground-level emission concentrations for selected typical and adverse meteorological conditions. The concentration values are extrapolated to extended averaging periods to permit comparison with state and federal air quality standards.

a) Effective Source Heights: Physical stack parameters necessary for effective source height determination are summarized in table B-39.

Stack exhaust velocities in excess of 30 m per sec do not normally cause downwash problems during high winds. Since the boiler, Stretford unit, miscellaneous gas stream and superheater stack velocities are about 27.4 per second, a potential for this effect exists unless stacks are properly designed. If the stack height is less than 2.5 times the adjacent building height, aerodynamic interaction between stack discharge and structures may also occur (another form of downwash).[1] These processes, particularly the latter, result in relatively high local pollutant concentrations.

Effective source heights computed from the Holland equation and preceding stack data are listed in table B-40 for selected stabilities and wind speeds. Plume rises calculated for the emergency relief used the 91 m per sec exit velocity for the momentum term in the Holland equation and the 1811° K combustion temperature for the buoyancy term instead of the 311° K pre-ignition exhaust temperature.

b) Ground-Level Concentrations: For a given effective source height and a fixed set of meteorological parameters, a maximum ground-level concentration will be experienced at some point along the plume length. These maximum concentrations have been calculated under selected meteorological conditions for each effluent from each of the five sources.[2] Tables B-41 through B-55 contain the estimated maximum ground-level concentrations for each of the sources and emissions, normalized to standard air quality time intervals. These estimates are compared with applicable National Ambient Air Quality Standards, proposed federal non-deterioration standards, and state Ambient Air Quality Standards.[2]

1 Scorer, R. S. 1958. Natural Aerodynamics (Pergamon Press).

2 Gamara, Kurt E., Williams, David L. 1974. Estimates of Effective Source Heights Required to Meet Air Quality Standards, Metronics Associates, Inc. Technical Report no. 195. February.

Table B-39. Summary of stack parameters

Parameter	Boiler	Sulfur plant (incinerated)	Emergency relief (flared)	Miscellaneous (incinerated)	Superheater
Stack height (m)	91	61	61	61	61
Stack exhaust velocity, (m/sec)	27.4	27.4	91.4	27.4	27.4
Inside stack diameter (m)	5.34	4.06	2.13	1.18	1.64
Stack exhaust temp. (°K)	450	450	1811 ignition 311 pre-ignition	450	450

Table B-40. Estimated effective source heights

Stability class	Wind speed mph, (m/sec)	Effective source height, meters: Boiler	Sulfur plant (incinerated)	Emergency relief (flared)	Miscellaneous (incinerated)	Superheater
A	2 (0.9)	1253[a]	798	1540[a]	170	232
A	5 (2.24)	558	357	655	105	130
D	7 (3.13)	358	231	410	86	100
D	21 (9.4)	180	117	174	69	74
F	2 (0.9)	866	553	1047[a]	134	175
F	7 (3.13)	313	202	344	82	94

(a) These values truncated at 914 meters for dispersion estimates as conservative measure.

Table B-41 Comparison of maximum ground-level concentrations to air quality standards for boiler plant.

Emission	NAAQS	Wyoming	Non-deterioration (a)	Sample time	A/2	A/5	D/7	D/21	F/2	F/7
	Standards, µg/m^3			Boiler plant						
					Stability class/wind speed, mph					
SO_2	60	60	15	Annual	N.A.	N.A.	3	6	--	--
	260	260	100	24-hr.	N.A.	N.A.	11	19	--	--
	1300	1300	300	3-hr.	108	91	17	29	--	--
				10-min.	192	163	31	52	--	--
Part.	60	60	10	Annual	N.A.	N.A.	0.5	1	--	--
	150	150	30	24-hr.	N.A.	N.A.	2	3	--	--
				10-min.	27	23	4.8	8	--	--
NO_x	100	100		Annual	N.A.	N.A.	4	6	--	--
				10-min.	189	170	34	57	--	--

(a) Proposed Standard

Table B-42 Comparison of maximum ground-level concentrations to air quality standards for Stretford sulfur plant.

Emission	NAAQS	Wyoming	Non-Deterioration (a)	Sample time	A/2	A/5	D/7	D/21	F/2	F/7
	Standards, µg/m^3			Stretford sulfur plant (incinerated)						
					Stability class/wind speed, mph					
SO_2	60	60	15	Annual	N.A.	N.A.	2	3	--	--
	260	260	260	24-hr.	N.A.	N.A.	6	10	--	--
	1300	1300	300	3-hr.	22	33	9	15	--	--
				10-min.	39	58	16	26		
NO_x	100	100		Annual	N.A.	N.A.	3	5.0	--	--
				10-min.	70	98	28	49	--	--

(a) Proposed Standard

Table B-43 Comparison of maximum ground-level concentrations to air quality standards for emergency relief system

Emission	NAAQS	Wyoming	Non-deterioration (a)	Sample time	A/2	A/5	D/7	D/21	F/2	F/7
	Standards, µg/m^3			Emergency relief system (flared)						
					Stability class/wind speed, mph					
SO_2	60	50	15	Annual	N.A.	N.A.	N.A.	N.A.	--	--
	260	260	100	24-hr.	N.A.	N.A.	0.4	0.9	--	--
	1300	1300	300	3-hr.	26	16	3.1	7.6	--	--
				10-min.	315	192	37	92	--	--
NO_x	100	100		Annual	N.A.	N.A.	N.A.	N.A.	--	--
				10-min.	399	276	43	106	--	--

(a) Proposed Standard.

Table B-44 Comparison of maximum ground-level concentrations to air quality standards for miscellaneous sources

Emission	Standards, μg/m³ NAAQS	Wyoming	Non-deterioration(a)	Sample time	A/2	A/5	D/7	D/21	F/2	F/7
					Miscellaneous sources (incinerated) — Stability class/wind speed, mph					
SO_2	60	60	15	Annual	N.A.	N.A.	3	2	1	1
	260	260	100	24-hr.	N.A.	N.A.	11	6	3	3
	1300	1300	300	3-hr.	37	32	16	9	4	5
				10-min.	66	58	29	16	8	9
NO_x	100	100		Annual	N.A.	N.A.	3	1	1	1
				10-min.	53	45	25	11	7	8

(a) Proposed standard

Table B-45 Comparison of maximum ground-level concentrations to air quality standards for superheater

Emission	Standards, μg/m³ NAAQS	Wyoming	Nondeterioration(a)	Sample time	A/2	A/5	D/7	D/21	F/2	F/7
					Superheater — Stability class/wind speed, mph					
SO_2	60	60	15	Annual	N.A.	N.A.	1	1	0.1	0.3
	260	260	100	24-hr.	N.A.	N.A.	3	3	0.4	1
	1300	1300	300	3-hr.	14	13	5	4	0.7	2
				10-min.	25	24	9	7	1	3
NO_x	100	100		Annual	N.A.	N.A.	3	2	.3	1
				10-min.	66	62	26	19	3	8

(a) Proposed Standard

Some values in the stability F columns of these tables are omitted because a few fundamental dispersion model assumptions are not applicable, due to the excessive transport time required to reach the location of maximum concentration. However, calculations for more reasonable distances indicate surface concentrations will still be unmeasurable, so these cases need not be considered in impact evaluations.

Distances to the maximum surface concentrations for the various meteorological regimes and effective source heights are plotted in figure B-40 and tabulated below in table B-46. Again, some values in the stability F rows are omitted for reasons discussed previously.

Table B-46. Distance to maximum ground-level concentration

Stability class	Wind speed, mph	Boiler	Sulfur plant (incinerated)	Emergency relief (flared)	Miscellaneous (incin.)	Superheater
		Distance to maximum ground-level concentration, km				
A	2	1.0	1.0	1.0	0.56	0.7
A	5	0.9	0.8	0.9	0.44	0.5
D	7	22	12	30	2.2	3
D	21	8	4.0	7.5	1.8	2
F	2	—	—	—	20	50
F	7	—	85	—	8.5	12

Plume fanning, looping and coning states are already inherently considered in the diffusion estimates for stabilities F, A and D, respectively. Calculations for plume fumigation, a transitory event with a stability change from F to A or B, typically lasts no longer than 30 to 60 minutes. Plume fumigation produces maximum ground-level concentrations ranging from 3 to 8 times greater than corresponding 10 minute stability F values. These concentrations are comparable in magnitude to corresponding 10 minute stability A concentrations and can be considered as such.

The other relevant condition is plume trapping, which occurs whenever stack emissions are emitted below a stable layer aloft. Under these circumstances the plume reflects downward, off the mixing surface top. The downwind distance to the first reflection is dependent on the height of the mixing layer, the height of the effective source, the wind speed and the stability in the mixing layer. This reflection results in higher downwind concentrations after the initial plume interaction. Limited meteorological data does not permit a detailed plume-trapping analysis. However, assuming an adverse 600-foot, stability A mixing layer, the maximum ground-level concentrations may increase by 1.2 to 2 times over the corresponding "no lid" case. Effects of other less severe but more frequent regimes are also not expected to have a significant effect on air quality standards.

2) Cooling Tower

Although regulatory emission standards are not applicable to cooling towers, the question of potential environmental impact must still be addressed. The approach used here considers atmospheric dispersion (applicable to drift only). As mentioned previously, atmospheric dispersion is governed by prevailing meteorological conditions, so due to the limited data, this analysis considers only extreme conditions.

a) Drift Losses: Cooling tower drift results from water droplets, mechanically generated within the tower, being entrained in the exhaust flow and discharged into the atmosphere. A major portion of these drift particles fall out near the tower. The location and amount depend on wind fields, droplet size to mass distributions, evaporation and condensation rates, etc. At any particular time these factors are related to the various interactive processes between the cooling tower plume and prevailing meteorological conditions.

Drift droplet size and mass distributions have been determined from recent studies on mechanical drift cooling towers.[1]

These distribution functions were utilized in a computerized drift trajectory model which incorporated droplet fall velocities, appropriate cooling tower and meteorological parameters, droplet curvature, and salinity effects on evaporation rates. Results indicated a typical 40 percent fallout within 400 feet, and 31 percent atmospheric dispersal.

1 Wistrom, G. V. and J. Z. Ovard. 1973. Cooling tower drifts, its measurement control and environmental effects.

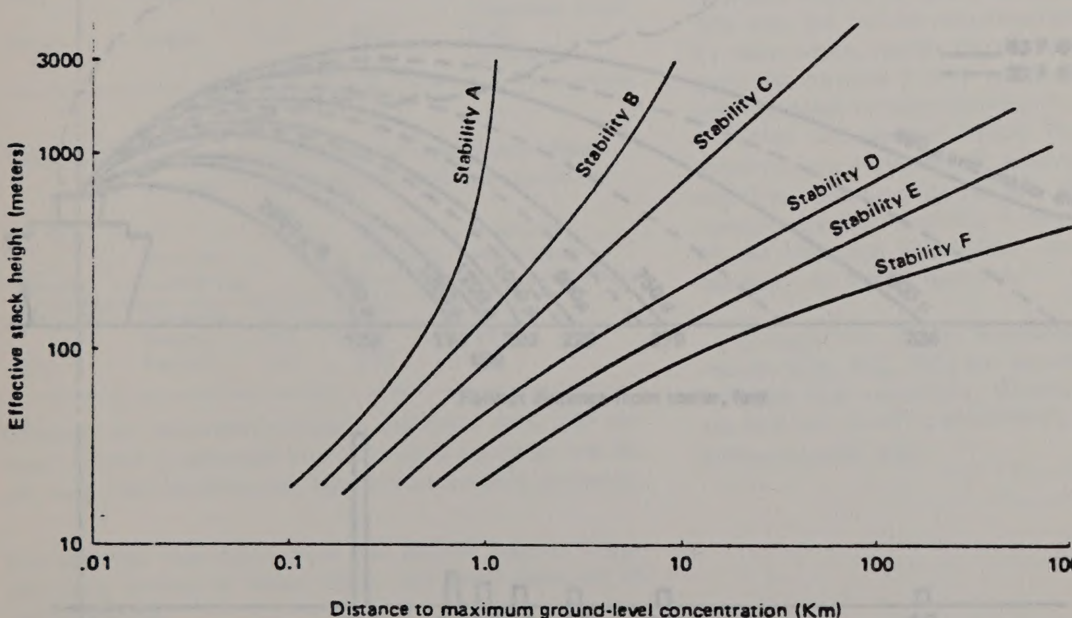

Figure B-40 Distance to maximum ground-level concentration compared to effective stack height

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Figure B-41 illustrates typical results for saline drift with 20 mph winds under two typical sets of temperature and relative humidity conditions. Note the 450 droplet fallout for the winter condition (T=32F, R.H.=80 percent) due to reduced evaporation.

Table B-35 shows that about 46,800 gallons per day of drift water is discharged, containing about 4000 lbs of salt. Assuming uniform deposition around the tower, 150 feet perpendicular to the major axis and 150 feet from each end of the complex, an estimated average deposition of 0.23 inches occurs each day. An additional 0.03 inches per day is estimated to fall out within the next 250 feet. Corresponding estimated salt deposition rates will be 4.5 lbs. per year per square foot within 150 feet and 0.5 lbs. per year per square foot within the next 250 feet. The actual annual deposition rate at a specific location is primarily a function of wind speed, wind direction and stability frequencies.

First-order estimates of ground-level concentration for the 31 percent dispersed drift mass can be evaluated using Gaussian diffusion theory. The extremely complex nature of wet plume and environmental interactive processes are currently not fully understood nor adequately modeled. Thus, conservative estimates of first-order effective source heights of 100 and 200 feet, derived from the Holland equation, are used in the analysis. Table B-47 contains ground-level concentrations as functions of downwind distance and atmospheric stability extremes for the two effective source heights.

b) **Evaporative Losses:** Tower evaporative losses should be relatively free of dissolved solids since it has undergone distillation. Consequently, environmental impacts from evaporative losses will depend solely upon effects from excess water.

It is estimated from diffusion analysis, similar to drift analysis, that the impact of additional atmospheric water vapor should be relatively limited and local except during certain winter conditions. Environmental modifications will be limited to a 2000 to 3000-foot radius from the tower. However, with low inversions and freezing temperatures, available water vapor can significantly extend the boundary of the effects.

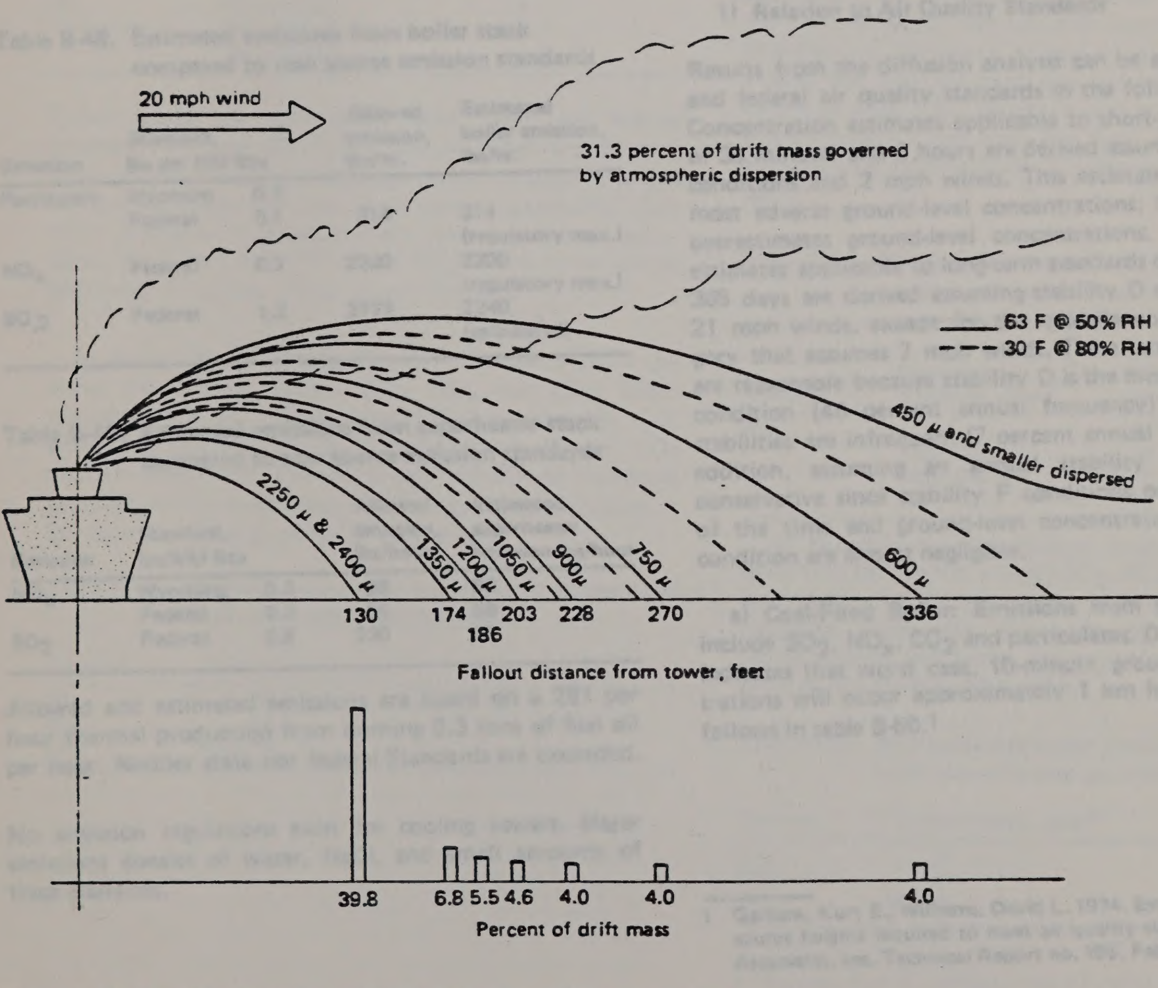

Figure B-41 Droplet dispersion and fallout from cooling tower plume

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Table B-47. Axial ground-level solid concentrations for 10 minute average

Effective source height, meters	Stability @ wind, m/sec	Concentrations for downwind distances,[a] $\mu g/m^3$ 0.2 km	0.3 km	0.5 km	0.7 km	1.0 km	2.0 km	5.0 km	10 km	20 km
61	A @ 1.57	0.3	160	90	37	13	2	–	–	–
61	F @ 2.24	0	0	0	0	0.1	14	40	30	18
30	A @ 1.57	340	300	100	40	13	2	–	–	–
30	F @ 2.24	0	0	12	80	190	250	120	60	30

(a) Gamara, Kurt D. 1973. Preliminary Environmental Impact Analysis for Proposed Six-Cell Crossflow Cooling Tower. Metronics Associates, Inc. Technical Report 190.

3. Source Emission Analysis

Estimated boiler stack emissions are compared to New Source Emission Standards for coal-fired boilers in table B-48. Allowed and estimated emissions are based on a 3143 per hour thermal production from burning 186 tons of coal per hour. Federal standards are not exceeded and NO_x and particulate emissions are at the allowed levels.

Estimated superheater stack emissions are compared to new Source Emissions Standards for oil-fired boilers in table B-49.

Table B-48. Estimated emissions from boiler stack compared to new source emission standards

Emission	Standard, lbs per MM Btu		Allowed emission, lbs/hr.	Estimated boiler emission, lbs/hr.
Particulate	Wyoming	0.1		
	Federal	0.1	314	314 (regulatory max.)
NO_x	Federal	0.7	2200	2200 (regulatory max.)
SO_2	Federal	1.2	3772	2240 (calculated)

Table B-49. Estimated emissions from superheater stack compared to new source emission standards

Emission	Standard, lbs/MM Btu		Allowed emission, lbs/hour	Estimated superheater emission lbs/hour
NO_x	Wyoming	0.3	86	86
	Federal	0.3	86	86
SO_2	Federal	0.8	230	51

Allowed and estimated emissions are based on a 287 per hour thermal production from burning 8.3 tons of fuel oil per hour. Neither state nor federal Standards are exceeded.

No emission regulations exist for cooling towers. Major emissions consist of water, NaCl, and small amounts of trace elements.

4. Impact Assessment

This section summarizes atmospheric information previously discussed and describes their related impacts.

a. Boiler, Sulfur Plant, Emergency Relief, Miscellaneous Gas Stream, and Superheater

Impacts of these sources are considered in terms of state and federal air quality standards, atmospheric visibility and possible synergistic and long-term effects.

1) Relation to Air Quality Standards

Results from the diffusion analysis can be applied to state and federal air quality standards in the following manner. Concentration estimates applicable to short-term standards of 30 minutes and 3 hours are derived assuming stability A conditions and 2 mph winds. This estimate results in the most adverse ground-level concentrations; the assumption overestimates ground-level concentrations. Concentration estimates applicable to long-term standards of 24 hours and 365 days are derived assuming stability D conditions with 21 mph winds, except for the miscellaneous source category that assumes 7 mph winds. These latter assumptions are reasonable because stability D is the most characteristic condition (46 percent annual frequency) and A and B stabilities are infrequent (7 percent annual occurrence). In addition, assuming an annual stability D category is conservative since stability F conditions occur 25 percent of the time and ground-level concentrations during this condition are almost negligible.

a) Coal-Fired Boiler: Emissions from the boiler stack include SO_2, NO_x, CO_2 and particulates. Diffusion analysis indicates that worst case, 10-minute, ground-level concentrations will occur approximately 1 km from the stack as follows in table B-50.[1]

1 Gamara, Kurt E., Williams, David L. 1974. Estimates of effective source heights required to meet air quality standards. Metronics Associates, Inc. Technical Report no. 195. February.

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Table B-50. 10 minute worst case ground-level concentrations from boiler

Emission	Concentration, $\mu g/m^3$
SO_2	192
NO_x	189
Particulates	27
CO_2	56,826

The short-term concentrations in this table are expected to occur during strong solar radiation and light winds (stability A).

Extrapolated ground-level concentrations are compared to air quality standards below in table B-51.

Table B-51. Comparison of maximum ground-level concentrations to air quality standards for coal-fired boiler

Emission	Wyoming standards, $\mu g/m^3$	Estimated maximum concentrations, $\mu g/m^3$
SO_2	1300 (3 hrs.)	180
	260 (24 hrs.)	19
	60 (annual)	6
NO_x	100 (annual)	6
Particulate	150 (24 hrs.)	3
	60 (annual)	1

These values are well below both state and federal standards and are also below the proposed federal nondeterioration standards. Although carbon dioxide emissions are not regulated by existing air quality standards, maximum ground-level concentrations were nonetheless calculated. The 57 mg/m^3, 10-minute CO_2 level is far below the 9000 mg/m^3, 8-hour OSHA health standard.

b) Sulfur Plant Off-Gas Stream: Emissions from the sulfur plant stack include SO_2, NO_x and CO_2. Other components in the off-gas stream (CO, hydrocarbons, H_2S, COS, CS_2, mercaptans) will be incinerated to SO_2 and CO_2 prior to stack exit. The worst case, 10-minute maximum ground-level concentrations will occur approximately 1 km from the stack as shown in table B-52.

Table B-52. 10-minute worst case ground-level concentrations from sulfur plant (incinerated)

Emission	Concentration, $\mu g/m^3$
SO_2	58
NO_x	98
CO_2	165,075

These conditions occur with stability A and 5 mph winds. Extrapolated ground-level concentrations are compared to air quality standards below in table B-53.

Table B-53. Comparison of maximum ground-level concentrations to air quality standards for sulfur plant (incinerated)

Emission	Wyoming standards, $\mu g/m^3$	Estimated maximum concentrations, $\mu g/m^3$
SO_2	1300 (3-hour)	33
	260 (24-hour)	10
	60 (annual)	3
NO_x	100 (annual)	5

All values are well below both the state and federal standards and the proposed federal nondeterioration standards. Again, maximum CO_2 ground-level concentrations (165 mg/m^3) are far below OSHA health standards.[1]

c) Emergency Relief System: Emissions from the emergency relief flare will include SO_2 and CO_2. The CO, hydrocarbons, H_2S, COS, CS_2, and mercaptans will be incinerated to SO_2 and CO_2 by the flare. The NH_3 component was assumed to be converted to N_2 and H_2O and the emergency flare will only operate for short periods. Therefore, a 15-minute release of the emission was considered and then averaged over the longer time periods as shown in table B-54. Maximum concentration should occur approximately 1 km from the flare. Again, no air quality standards are exceeded and CO_2 concentrations are insignificant.

Table B-54. Comparison of maximum ground-level concentrations to air quality standards for emergency relief flare

Emission	Wyoming standards, $\mu g/m^3$	Estimated maximum concentrations, $\mu g/m^3$
SO_2		315 (10 min) worst case
	1300 (3-hour)	26
	260 (24-hour)	1
NO_x	NA	399 (10 min) worst case

d) Miscellaneous Gas Stream: Emissions from the miscellaneous gas streams include SO_2, NO_x and CO_2. The CO, hydrocarbons and H_2S will be incinerated prior to stack discharge. Worst case, 10-minute, maximum ground-level concentrations will occur approximately 0.9 km from the stack as presented in table B-55.

Table B-55. 10 minute worst case ground-level concentrations from miscellaneous gas stream (incinerated)

Emission	Concentration, $\mu g/m^3$
SO_2	66
NO_x	53
CO_2	85,329

1 Gamara, Kurt E., Williams, David L. 1974. Estimates of effective source heights required to meet air quality standards. Metronics Associates, Inc. Technical Report no. 195. February.

The above conditions occur with stability A and 2 mph winds. Their extrapolated ground-level concentrations are compared to air quality standards in table B-56. No state or federal standards will be exceeded including the proposed federal nondeterioration standard and calculated CO_2 levels are insignificant.

Table B-56. Comparison of maximum ground-level concentrations to air quality standards for miscellaneous gas stream (incinerated)

Emission	Wyoming standards, $\mu g/m^3$	Estimated maximum concentration, $\mu g/m^3$
SO_2	1300 (3-hour)	37
	260 (24-hour)	11
	60 (annual)	3
NO_x	100 (annual)	3

e) Superheater: Emissions from the superheater stack include SO_2 and CO_2. Worst case 10-minute maximum ground-level concentrations will occur at approximately 0.6 km from the stack as presented in table B-57. These conditions occur with stability A and 2 mph winds.

Table B-57. 10 minute worst case ground-level concentrations from superheater stack

Emission	Concentration, $\mu g/m^3$
SO_2	25
NO_x	66
CO_2	25,734

Extrapolated ground-level concentrations are compared to air quality standards below in table B-58. All values are well below both the state and federal standards and the proposed federal nondeterioration standards. Calculated CO_2 levels are insignificant.

Table B-58. Comparison of maximum ground-level concentrations to air quality standards for superheater

Emission	Wyoming standards, $\mu g/m^3$	Estimated maximum concentration, $\mu g/m^3$
SO_2	1300 (3 hr.)	14
	260 (24 hr.)	5
	60 (annual)	1
NO_x	100 (annual)	3

f) Combined Emissions: Accurate analysis of the combined effects of all emissions from all sources is not yet available due to the preliminary stages of both the plant engineering design, data and meteorological information.

A first estimate of the combined effects was made by adding all of the maximum concentrations together. This assumes that the maximum concentrations generated from each source would occur at the same time and place. However, this situation would never occur because pollutants are released at different heights and are subject to different transport mechanisms, so that maximum concentrations would not only occur at different radial distances from the source but also in different sectors. Therefore, these results represent an overestimate of the total impact.

With all sources combined, all air quality standards will be met as indicated below in table B-59.

Table B-59. Comparison of maximum ground-level concentrations to air quality standards for total of all sources combined

Emission	Wyoming standards, $\mu g/m^3$	Estimated maximum concentration, $\mu g/m^3$
SO_2	10 min. worst case	637
	1300 (3 hr.)	718
	260 (24 hr.)	44
	60 (annual)	13
NO_x	10 min. worst case	745
	100 (annual)	17
Particulate	10 min. worst case	27
	150 (24 hr.)	3
	60 (annual)	1

Based on annual wind direction frequencies observed at Moorcroft, winds from the southeast through south-southwest (42 percent frequency) will blow gasification plant emissions to the north. The second most frequent wind direction blows from the north through the west-northwest at an annual frequency of 32 percent and will blow plant emissions to the southeast.[1]

Using standard diffusion calculations with the most frequently occurring stabilities and wind speeds, maximum annual ground level concentrations would occur between 1 and 10 km north and southeast of the plant. Highest short-term concentrations will occur under infrequent adverse meteorological conditions approximately 0.6 to 1 km from the plant.

The impact of disturbances cannot be specifically addressed because definitive data are not available; however, any significant variation in source strength could considerably alter specific impacts. For example, if sulfur plant tail-gas with a specified 99.5 percent sulfur removal efficiency drops to 95.5 percent under upset conditions, ground-level concentrations will increase 10-fold. Likewise, significant long-term variations in feed-coal composition or process-rate emissions will also modify the conditions.

Transport of emissions to the Black Hills Region is not expected. Analysis of the wind direction frequencies for Casper and Moorcroft indicate that air flow from the west curves to either the north or south. The prevailing direction at Casper is from the west-southwest. At Moorcroft the prevailing direction is from the southeast with significant frequencies from the north. The initial wind data taken at the mine site correlate well with the Moorcroft data.

Also, diffusion analysis based on limited data indicate that transport of emissions into the substandard North Platte River Valley will be insignificant.

1 Gamara, Kurt E. 1974. Atmospheric Environment of Northern Wyoming, Climatology/Air Quality/Air Pollution Factors. Metronics Report P-813. January.

2) Impact on Visibility

The most obvious indication of air quality degradation is the occurrence of reduced visibility. Even though air quality standards based on health effects are met, there is the possibility that adverse public opinion will be generated if reduced visibility occurs.

Particulates released into the air scatter and absorb light, thus reducing the ability to see distant objects. Particles are also formed by photochemical reactions and the conversion of SO_2 to sulfates. Although it is known that there is some conversion of NO_x and SO_2 to nitrates and sulfates, no quantitative data are available.

A department of Health, Education and Welfare publication[1] gives a correlation of particulate concentration and visibility in table B-60.

Table B-60. Visibility for various particulate concentrations

Area	Particulate concentration, $\mu g/m^3$	Visibility
Rural	30	25 miles
Urban	100	7.5 miles
	200	3.75 miles

Maximum particulate concentration from the coal-fired boiler stack under the most adverse conditions was calculated at 27 μg per m^3. A realistic estimate for time periods that allow transport from 25 to 50 miles from the plant are in the range of 0.04 to 1.3 μg per m^3. Assuming 50 percent conversion of SO_2 and NO_x to particulates during stability F, a maximum of 2.2 μg per m^3 would be added. Therefore, total particulate, sulfate and nitrate maximum concentration would be 3.5 μg per m^3. This total would represent only 10 percent of the rural particulate concentration that allows a 25-mile visibility.

3) Synergestic Effects

In high concentrations, interaction between SO_2 emissions and fugitive dust could increase the effect of each other. Synergistic effects between wet cooling tower plume and stack emissions may also occur. At this point, these possible effects and subsequent impacts are only speculation.

4) Long-Term Effects

Such factors as reduced surface insolation, increased atmospheric sulfate and nitrate loading, rain acidifications, and increased atmospheric CO_2 concentrations, may engender long-term effects. Present understanding of air pollution and its potentially adverse impact on the environment is seriously deficient in many aspects, particularly in regard to long-term synergistic effects.

b. Cooling Tower

Although regulatory emission standards are not applicable to cooling towers, the question of potential environmental impact must still be addressed. The following discussion summarizes the effects caused by evaporative loss and cooling tower drift.

1) Evaporative Losses

Tower evaporative losses should be relatively free of dissolved solids having undergone distillation. Consequently, evaporative loss related environmental impact will depend solely upon effects engendered by excess water vapor. It is estimated that the impact of additional atmospheric water vapor should be relatively limited and local, except during certain winter conditions. Typical environmental modifications due to humidity increases will be limited to a 2000 to 3000 ft. radius from the tower. However, with low inversions and freezing temperatures, available water vapor can significantly extend the boundary of these effects.[2]

Rain, drizzle, or snow can occur around the site from the plume becoming supersaturated and subsequently nucleating. This condition could also cause fog, leading to reduced visibility, acceration and icing on adjacent structures. Documented occurrences of 100 hours per year of additional fog have been attributed to cooling tower discharge.[3] Cooling tower plumes have obscured highway vision, which have directly resulted in traffic fatalities. On a lesser scale, large white dense plumes may attain 1000-foot heights on frequent occasions, and thus be visible for many miles.

2) Drift Losses

Cooling tower drift results from water droplets, mechanically generated within the tower, being entrained in the exhaust flow to the atmosphere. A major portion of these drift particles fall out within a relatively short distance from the tower. Their composition should be similar to tower circulating water and should be responsible for some environmental contamination. It is estimated that significant drift effects will be confined within a 2000-foot radius of the site. Major environmental interaction occurs within a 400 to 500-foot radius where 60 to 70 percent of the drift mass falls out under typical meteorological conditions. Here excessive amounts of dissolved solids may accumulate (about 2800 lbs per day), subsequently engendering corrosion and vegetation damage.

During the winter, rime may occur on the tower and structures within the immediate plant vicinity. Its deposition amount and rate at a particular location is dependent primarily upon wind direction, speed and stability frequencies.

1 DHEW. Air Quality Criteria for Particulate Matter.

2 Gamara, Kurt E. 1973. Preliminary Environmental Impact Analysis for Proposed Six-Cell Crossflow Cooling Tower. Metronics Associates, Inc. Technical Report no. 190.

3 Southwest Energy Study. Report of the Meteorological Work Group. B.P.A.

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The most obvious indication of air quality degradation is the occurrence of reduced visibility. Even though air quality standards based on health effects are met, there is the possibility that adverse public opinion will be generated if reduced visibility occurs.

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Area	Particulate concentration, $\mu g/m^3$	Visibility
Rural	30	25 miles
Urban	100	7.5 miles
	200	3.75 miles

Maximum particulate concentration from the coal-fired boiler stack under the most adverse conditions was calculated at 72 μg per m^3. A realistic estimate for time periods that allow transport from 25 to 50 miles from the plant are in the range of 0.64 to 1.3 μg per m^3. Assuming 50 percent conversion of SO_2 and NO_x to particulates during stability F, a maximum of 2.7 μg per m^3 would be added. Therefore, total particulate, sulfate and nitrate maximum concentration would be 3.5 μg per m^3. This total would represent only 10 percent of the rural particulate concentration that permits a 25-mile visibility.

3) Synergistic Effects

In high concentrations, interaction between SO_2 emissions and fugitive dust could enhance the effect of each other. Synergistic effects between wet cooling tower plume and stack emissions may also occur. At this time, these possible effects and subsequent impacts are only speculation.

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1. DHEW, Air Quality Criteria for Particulate Matter.

2. Gerrens, Karl E. 1973. Preliminary Environmental Impact Analysis for Proposed Six-Cell Crossflow Cooling Tower, Westcona Associates, Inc. Technical Report no. 190.

3. Southwest Energy Study, Report of the Meteorological Work Group, E.P.A.

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F. ATMOSPHERIC IMPACT OF TRAFFIC GENERATED BY THE PROPOSED WYOMING GASIFICATION PROJECT

The construction and operation of the proposed project will increase both light duty passenger vehicle traffic and heavy duty commercial traffic. The increased flux will mainly affect sections in Wyoming highway 59 within the Douglas city limits and sections 15.5 miles and 55.9 miles north of Douglas. The intensity of vehicle travel for the three sections depends upon final selection of the plant location and the phase of plant construction or operations. The project will generate maximum traffic during the projected peak construction year of 1977 and the peak operational year of 1980.

The impact of traffic emission on the environment can be divided into mesoscale and microscale effects.

Mesoscale effects consider the large scale impact of highway emissions upon the air quality within the Casper Intrastate Air Quality Control Region (CIAWCR). The regional burden of pollutants is expressed in terms of additional tons of emissions per year generated by the increased traffic. Traffic parameters required for mesoscale predictions are vehicle miles per day, average traffic speed, and percentage of heavy-duty vehicles (6,000 lbs. G.V.W.).

Microscale effects are limited to points immediately downwind of a roadway line source. The microscale prediction is more complex than the mesoscale analysis since it involves the additional parameters of wind speed, crossroad wind angle, atmospheric stability, peak hour traffic (vehicles per hour), average vehicle speed and age and highway altitude. This information is then averaged into time periods comparable to the ambient air quality standards by using a fifth power law.

1. Summary

Traffic generated as a result of the gasification project should not cause any significant deterioration of air quality within the CIAQCR. Mesoscale computations for carbon monoxide and hydrocarbons indicate that even during the peak construction year of 1977, traffic associated with the project will contribute less than one percent of the total annual emissions of these gases within the CIAQCR. This should have no effect on the region's hydrocarbon Priority III classification.

No deterioration of human health in the vicinity of the highway should occur even under the most adverse conditions. Worst case concentrations for Douglas amount to 36 percent of the federal hydrocarbon Secondary Standard and occur at a distance 100 feet from the roadway. This condition has a probability of occurring less than 3 percent during 1977. The Douglas residential area most affected is a corridor less than 500 feet wide, where emissions generated by the project traffic are typically less than 10 percent of their respective standards.

2. Mesoscale Impact

Mesoscale predictions are most significant in terms of regional air quality impact. Projections of annual highway emissions for hydrocarbons and carbon monoxide were computed for 1977 and 1980. Three sections of roadway were considered: 2.6 miles of main streets within the Douglas city limits (shown in figure B-42), a section of highway 59 extending to 15.5 miles north of Douglas and representing traffic to the south plant site, and a section of highway 59 extending 55.9 miles north of Douglas representing traffic to the north site. Assessment of annual traffic emissions are computed using traffic projections without the project, so that increased emission output resulting from the project traffic can be estimated. Table B-61 lists the traffic parameters used in this mesoscale study.[1]

Table B-61. Douglas vicinity mesoscale traffic impact parameters

Highway 59 road sector	Estimated vehicle miles per day VMD(a): Peak construction yr., 1977	Peak operational yr., 1980	Average speed of traffic, mph	Percent heavy duty traffic
Douglas City street				
South site	35,098	38,750	15	5
North site	31,346	37,956	15	5
Without project	20,282	25,467	15	5
Highway 59, extending 15.5 miles north of Douglas				
South site	67,871	25,860	40	10
Without project	12,000	14,250	40	10
Highway 59, extending 55.9 miles north of Douglas				
North site	97,976	49,151	40	20
Without project	39,900	47,450	40	20

Tons emission per year = (VMD) x (Emission Factor) x (4.098×10^{-4}), where the numerical constant converts grams to tons, and days to years.

(a) Wyoming State Highway Department Planning Division and SERNCO Denver. 1973. Traffic projections for the Wyoming gasification project

A total output of 924 tons of carbon monoxide is projected[2] for the mine during 1977. Of this total, 548 tons would be attributed to traffic generated by the project, which is only 3 percent of the CIAQCR carbon monoxide output by motor vehicles and less than 0.4 percent of the total projected carbon monoxide output by all sources.

The selection of the south site would cause a significant increase in hydrocarbon and carbon monoxide emissions on highway 59 resulting from construction crews commuting

1 Wyoming State Highway Department Planning Division and SERNCO Denver. 1973. Traffic projections for the Wyoming gasification project.

2 California Division of Highways. 1972. Mathematical approach to estimating highway impact on air quality, prepared in cooperation with the Federal Highway Administration. July.

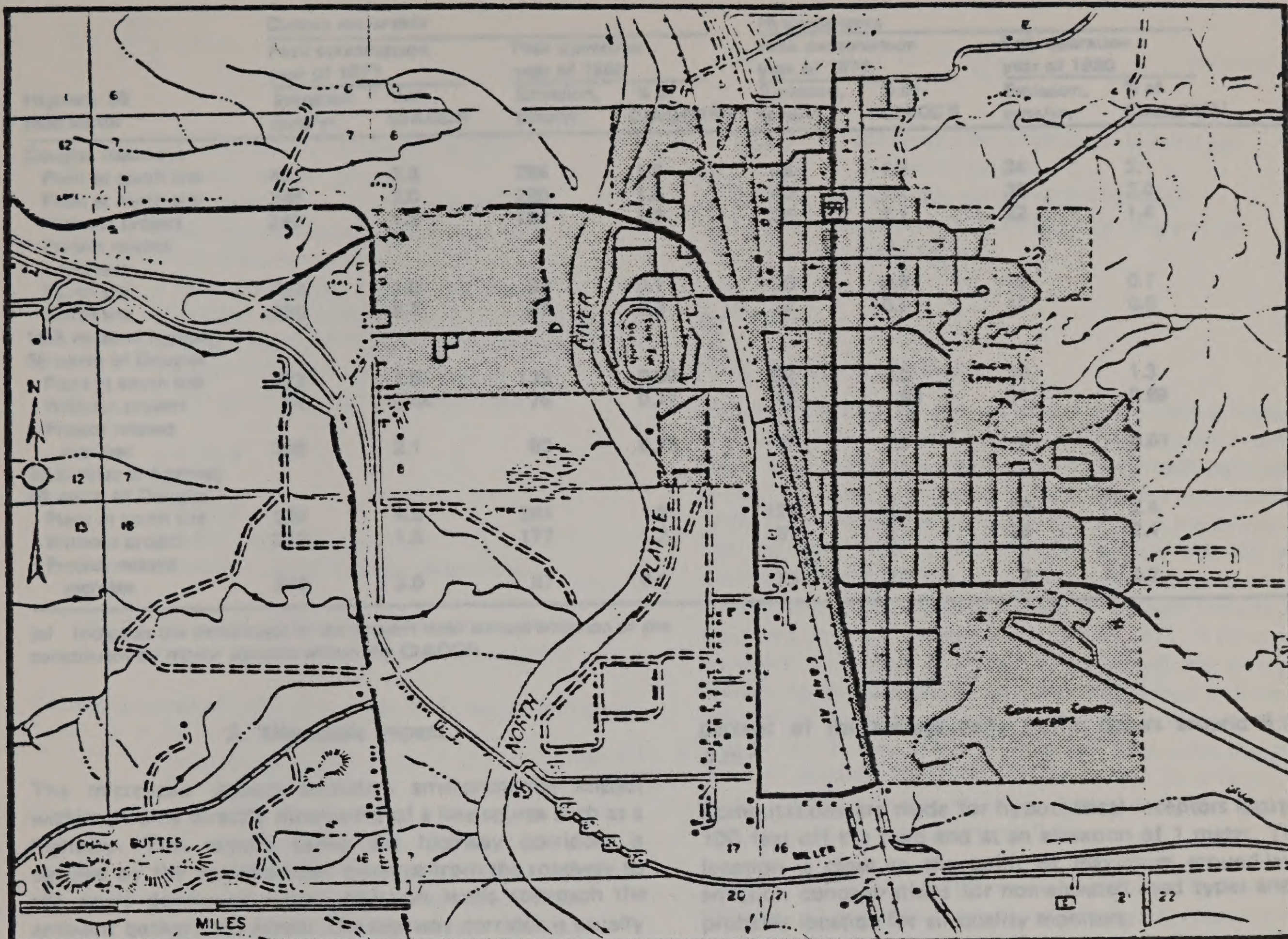

Figure B-42 Map of Douglas City streets

to and from the project. It is assumed that the commuter traffic would be reduced if the north site were selected because many goods and services would be provided on site.[1]

A hydrocarbon output of 124 tons is expected from the mine sector during the peak 1977 traffic year. This includes emissions from both project operation and baseline traffic. A total of 73 tons of hydrocarbons can be attributed to traffic generated by the project during this peak year. Thus, hydrocarbon emissions associated with the project should represent only abut 2.7 percent of the CIAQCR output of hydorcarbons by motor vehicles and less than 0.5 percent of the total hydrocarbon output by all sources.[2]

Table B-62 summarizes the mesoscale computations. Traffic contributions of hydrocarbons and carbon monoxide associated with the project are all less than 3 percent of the total CIAQCR output of hydrocarbons and carbon monoxide by motor vehicles projected for both the peak construction and operational year.

1 Wyoming State Highway Department Planning Division and SERNCO Denver. 1973. Traffic projections for the Wyoming gasification plant.

2 Gamara, Kurt E. 1974. Atmospheric environment of northern Wyoming, climatology/air quality/air pollution factors. January.

Table B-62. Douglas vicinity mesoscale traffic emissions

Highway 59 road sector	Carbon monoxide				Hydrocarbons			
	Peak construction year of 1977		Peak operation year of 1980		Peak construction year of 1977		Peak operation year of 1980	
	Emission, tons/yr.	% of CIAQCR	Emission, tons/yr.	% of CIAQCR[a]	Emission, tons/yr.	% of CIAQCR	Emission, tons/yr.	% of CIAQCR[a]
Douglas roadways								
Plant at south site	422	2.3	286	1.9	46	1.9	34	2.1
Plant at north site	385	2.0	280	1.8	40	1.7	32	2.0
Without project	249	1.3	187	1.2	26	1.1	22	1.4
Project related increase								
South site	193	1.0	99	0.7	20	0.8	12	0.7
North site	136	0.7	93	0.6	14	0.6	10	0.6
15.5 miles of highway 59 north of Douglas								
Plant at south site	473	2.5	138	0.92	92	3.5	20	1.3
Without project	84	0.44	76	0.17	15	.60	11	0.69
Project related increase	389	2.1	62	0.75	77	2.9	9	0.61
55.9 miles of highway 59 north of Douglas								
Plant at north site	924	4.9	264	1.8	124	4.8	38	2.4
Without project	376	1.9	177	1.2	51	2.1	36	2.4
Project related increase	548	3.0	87	0.6	73	2.7	2	0.2

(a) Indicates the percentage of the project total annual emission of the constituent by motor vehicles within the CIAQCR.

3. Microscale Impact

The microscale impact considers environmental impact within an area directly downwind of a line source such as a highway. This region, called the highway corridor, is defined by the perpendicular distance from the roadway to the point downwind where emission levels approach the ambient background levels. The highway corridor is usually a region of high emission concentrations and thus maximum environmental impact.

Concern was mainly focused on the more densely inhabited Douglas residential area because it is near highway 59. The three sections of highway 59 considered are all oriented north-south and are the same sections previously described in the mesoscale analysis. The two northern sectors are less significant because projected side street traffic does not contribute to background levels. In all cases, microscale computations for carbon monoxide, hydrocarbons, nitrogen dioxide, sulfur dioxide and particulate concentrations were performed.

The microscale analysis is more complicated than the mesoscale analysis because both traffic and meteorological parameters must be considered. The standard traffic factors used were developed by the Environmental Protection Agency.[1] Annual Moorcroft meteorological data were used for wind speed, direction and stability.

Two traffic conditions are considered: typical ($\phi = 22.5°, \overline{u} = 5$ m/sec) and adverse ($\phi = 22.5°$, $\overline{u} = 2$ m/sec). It is assumed that 12 percent of the projected average weekday traffic will occur during the daily peak traffic hours. Most rural commuter traffic studies indicate that about 10 percent of the average daily traffic occurs around 5:00 p.m.[2]

Computations are made for hypothetical receptors located 100 feet off the road and at an elevation of 1 meter. This location is close to the point of maximum ground-level emission concentrations for non-elevated road types and a probable location for air quality monitors.

ϕ = The crossroad wind angle corresponding to a 16 point compass.

$\overline{u}$ = Mean wind speed over averaging period.

a. Calculations for the Microscale Impact[3]

1) Mixing Cell Concentrations

The concentration of emissions on the highway within the mechanical mixing cell for highways located on elevated, cut, or at-grade sections may be estimated (for any surface stability class) by using the following equation for ϕ greater than 12 degrees.

1 United States Environmental Protection Agency. 1973. Compilation of air pollutant emission factors, 2nd edition. April.

2 California Division of Highways. 1972. Mathematical approach to estimating highway impact on air quality. Prepared in conjunction with the Federal Highway Administration. July.

3 Nunes, R. A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Associates, Inc. Technical Report no. 192. January.

$$C = \frac{1.06Q}{K_1 \bar{u}} \sin \phi \qquad \text{equation (1)}$$

where

- C = Concentration of emission, gm/m^3
- Q = Emission source, gm/sec-m
- $\bar{u}$ = Wind speed, m/sec (1 mph = 0.447 m/sec)[1]
- K_1 = Empirical coefficient determined by field measurements[2]
- ϕ = Angle of wind with respect to highway alignment as determined from the computer program (5) WNDROS or STAROS based on a 16 point compass reporting system. ϕ will be one of the following angles:

  $\phi = 22.5^\circ$
  $\phi = 45^\circ$
  $\phi = 67.5^\circ$
  $\phi = 90^\circ$ (wind direction perpendicular to highway alignment)

- 1.06 = Empirical factor relating the height of the mechanical mixing cell to concentration.

The source strength term Q in equation 1, can be computed from: $Q = (1.73 \times 10^{-7}) \times$ (vehicles per hour) x (E) equation (2)

where,

- 1.73×10^{-7} = coefficient which converts units of the prduct (vph) x (gm/mi) to gm/m-sec.
- E = emission factor which depends on the model year, emission standards, percentage of HDV, average route speed, and altitude

The calculated concentration from equation 1 can be converted to parts per million by using equation 4 below.

2) Receptor Concentrations

The following equation is used to establish the downwind pollutant concentration from at-grade, highway sections with elevated receptors and crosswind conditions:

$$C = \frac{Q}{K_1 \sigma_z \bar{u} \sin \phi} \quad \exp \left[-\frac{1}{2} \left(\frac{z}{\sigma_z} \right)^2 \right] \text{equation (3)}$$

where,

- $K_1, C, Q, \bar{u}, \phi$ = parameters previously described
- z = height of receptor above surrounding terrain, m
- σ_z = vertical dispersion parameter, m

The following equation converts concentrations in grams per cubic meter to parts per million by volume based on the reference temperature of 25 C and pressure of 760 mm of mercury:

$$C_{ppm} = 2.45 \times 10^{-8} \frac{Cg/m^3}{M.W.} \qquad \text{equation (4)}$$

where,

- C_{ppm} = concentration of emission in parts per million by volume
- M.W. = molecular weight of the emission
- Cg/m^3 = concentration of emission in grams per cubic meter

b. Results

1) Douglas Residential

Results computed for the peak construction phase indicate that under both adverse and typical meteorological conditions, only the hydrocarbon emissions approach significant levels. However, it must be noted that the hydrocarbon levels are projected to be significant even if the project is not initiated. The sulfur dioxide, carbon dioxide and particulate levels will not be significant even under the most adverse conditions. Significant loads of nitrogen dioxide are projected only for adverse conditions in 1977, if the south plant site is selected. It should be recognized that nitrogen dioxide projections are based upon the annual arithmetic mean of peak traffic hour levels of nitrogen dioxide. If the average traffic flux over a 24-hour period is used, then the nitrogen dioxide figure could be reduced by a factor of four. The quantitative results of these computations are plotted on figures B-43 through B-47.

The downwind concentrations of emissions from traffic approach background levels at a rate inversely proportional to atmospheric stability. Values decrease in a typical Gaussian relationship as one travels downwind from the non-elevated line source. Highway emission corridors are usually about 1000 feet for high stability, 400 feet for neutral stability and 200 feet for low stability.

These emission corridors should pose no health threat to the downwind residents of Douglas. The computed highway emission concentrations never approach more than 40 percent of the Federal Health Standards, even directly adjacent to the roadside under the most adverse conditions. These computations are summarized in table B-63.

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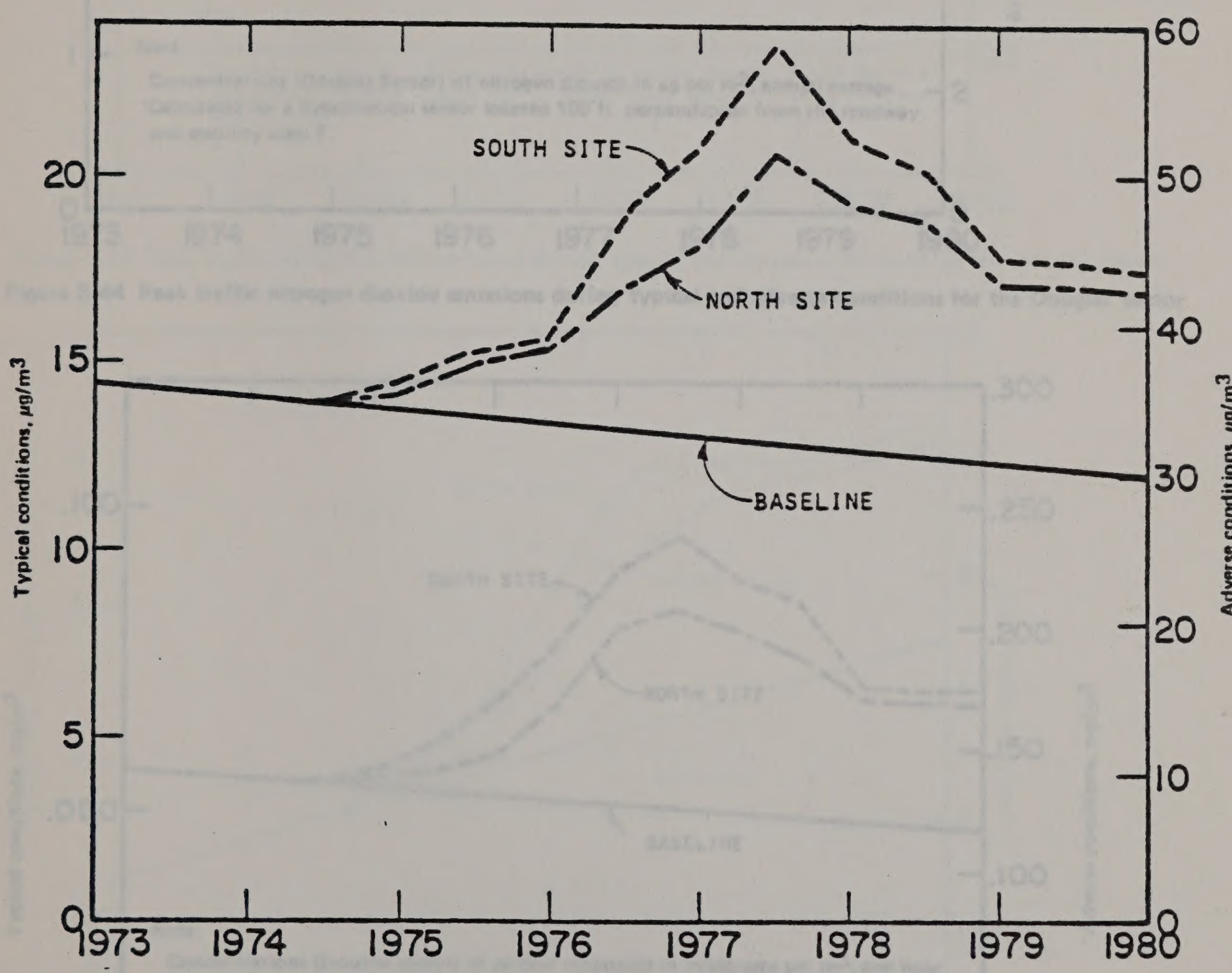
1 The minimum recommended wind speed is 2 mph or about 1 m/sec.

2 Until sufficient data become available from the Division of Highway Research Project (10), assume $K_1 = 4.42$.

Table B-63. Douglas air quality during peak hour traffic and adverse meteorological conditions

Emission	Year	Concentrations in percent of Federal Secondary Air Quality Standard[a]: Plant at south site	Plant at north site	Without project
HC	1977	36%	31%	19%
	1980	27%	26%	19%
NO_2	1977	11%	9%	6%
	1980	9.5%	9.2%	6.1%
Part.	1977	6.7%	5.5%	4%
	1980	7.3%	6.7%	4.7%
CO	SO_2 less than 1 percent of their respective Federal Secondary Air Quality Standard			

(a) Computed for location 100 feet perpendicular distance from the roadway and stability class F.



Note: Concentrations (Douglas sector) of hydrocarbons in µg per m^3, three hour average. Federal Secondary Standard: 160 µg per m^3, three hour average. Calculated for a hypothetical receptor located 100 ft. perpendicular distance from the roadway and stability class F.

Figure B-43 Peak traffic hydrocarbon emissions during typical and adverse conditions for the Douglas sector

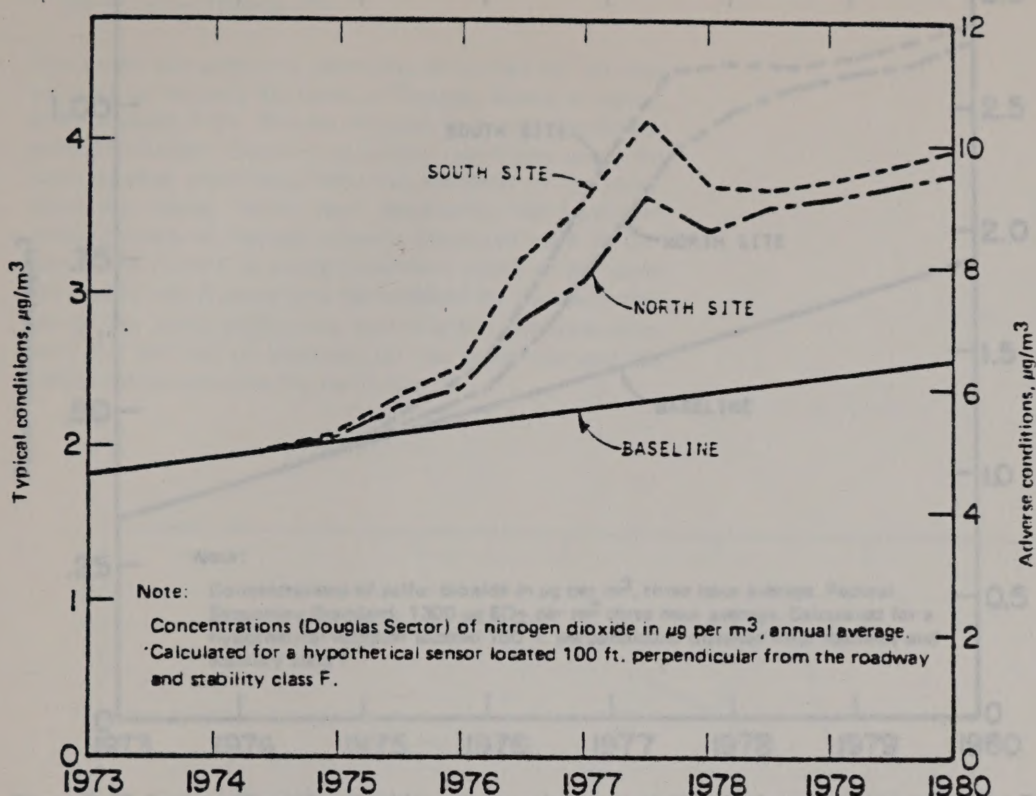


Figure B-44 Peak traffic nitrogen dioxide emissions during typical and adverse conditions for the Douglas sector

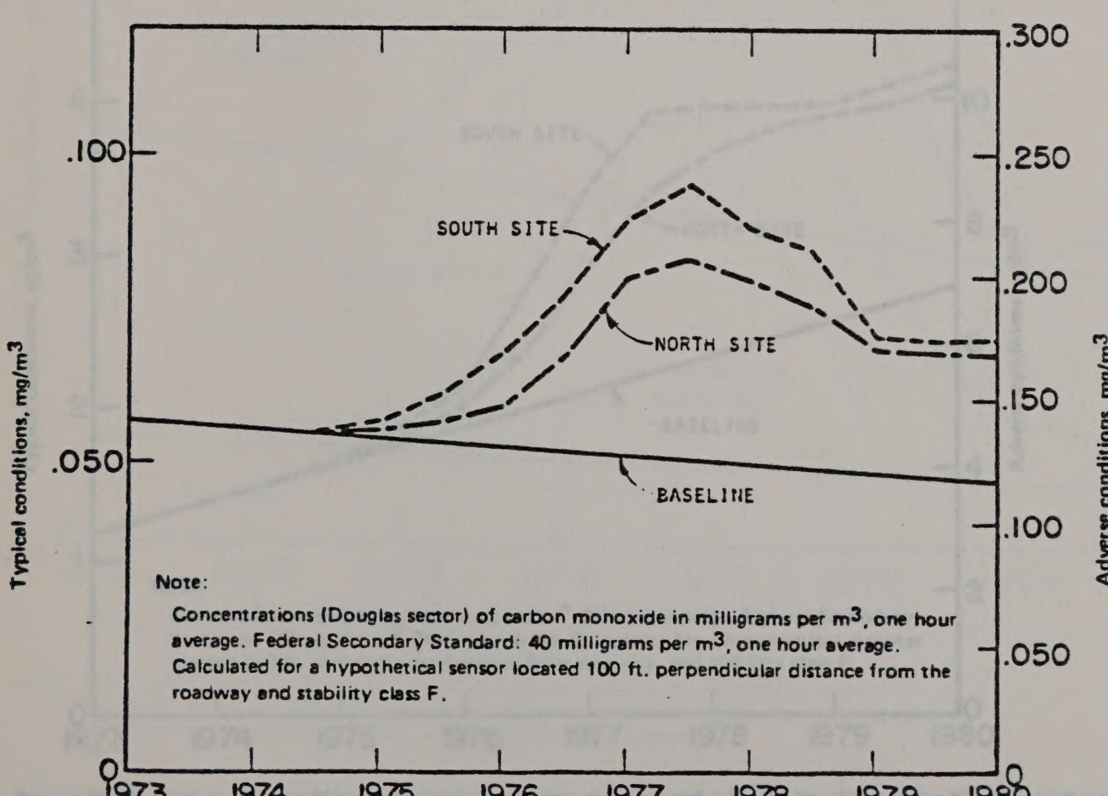


Figure B-45 Peak traffic carbon monoxide emissions during typical and adverse conditions for the Douglas sector

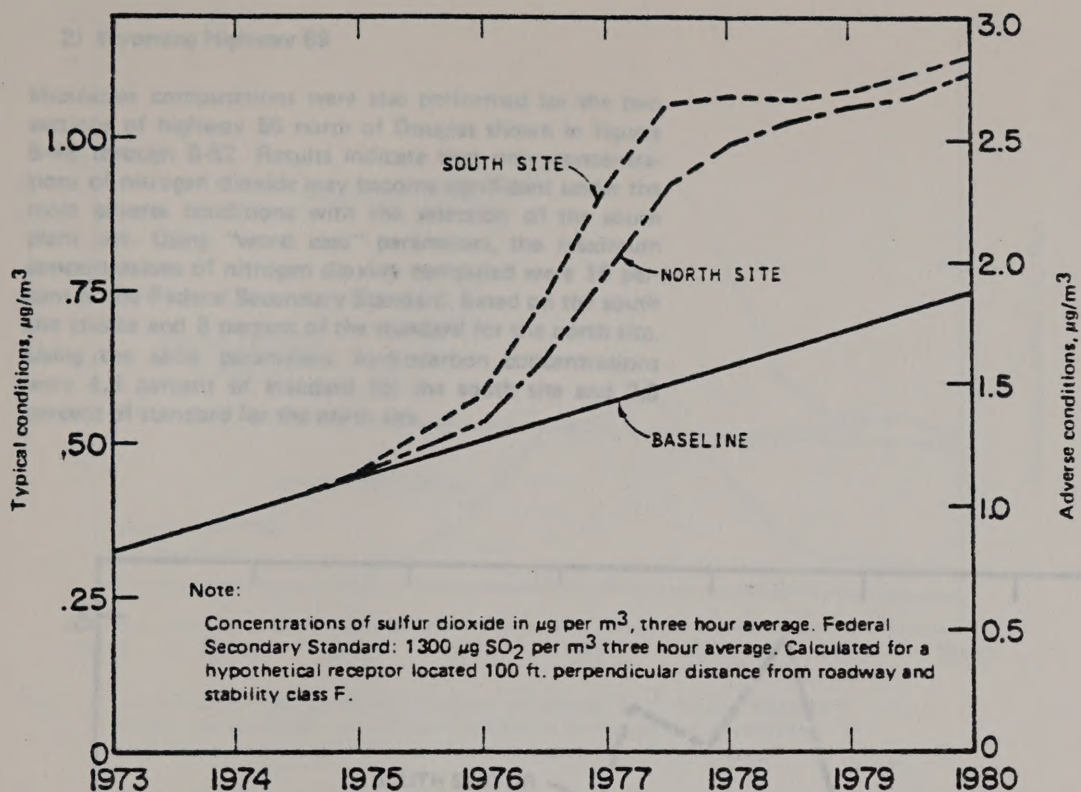


Figure B-46 Peak traffic sulfur dioxide emissions during typical and adverse conditions for the Douglas sector

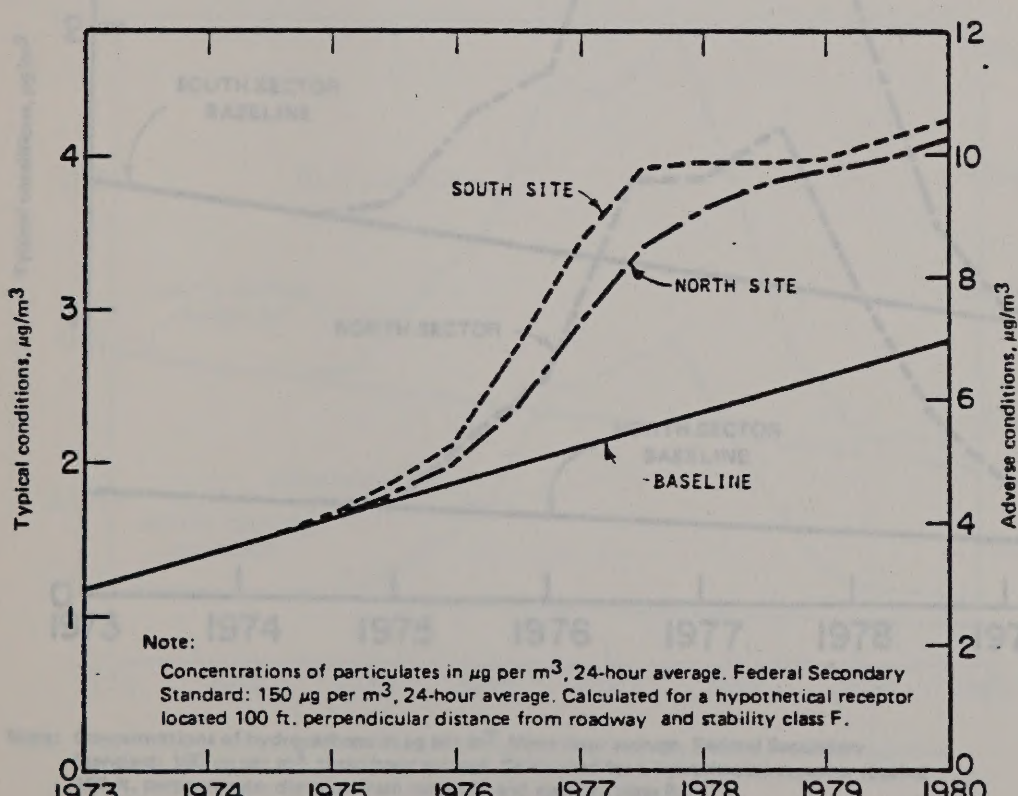
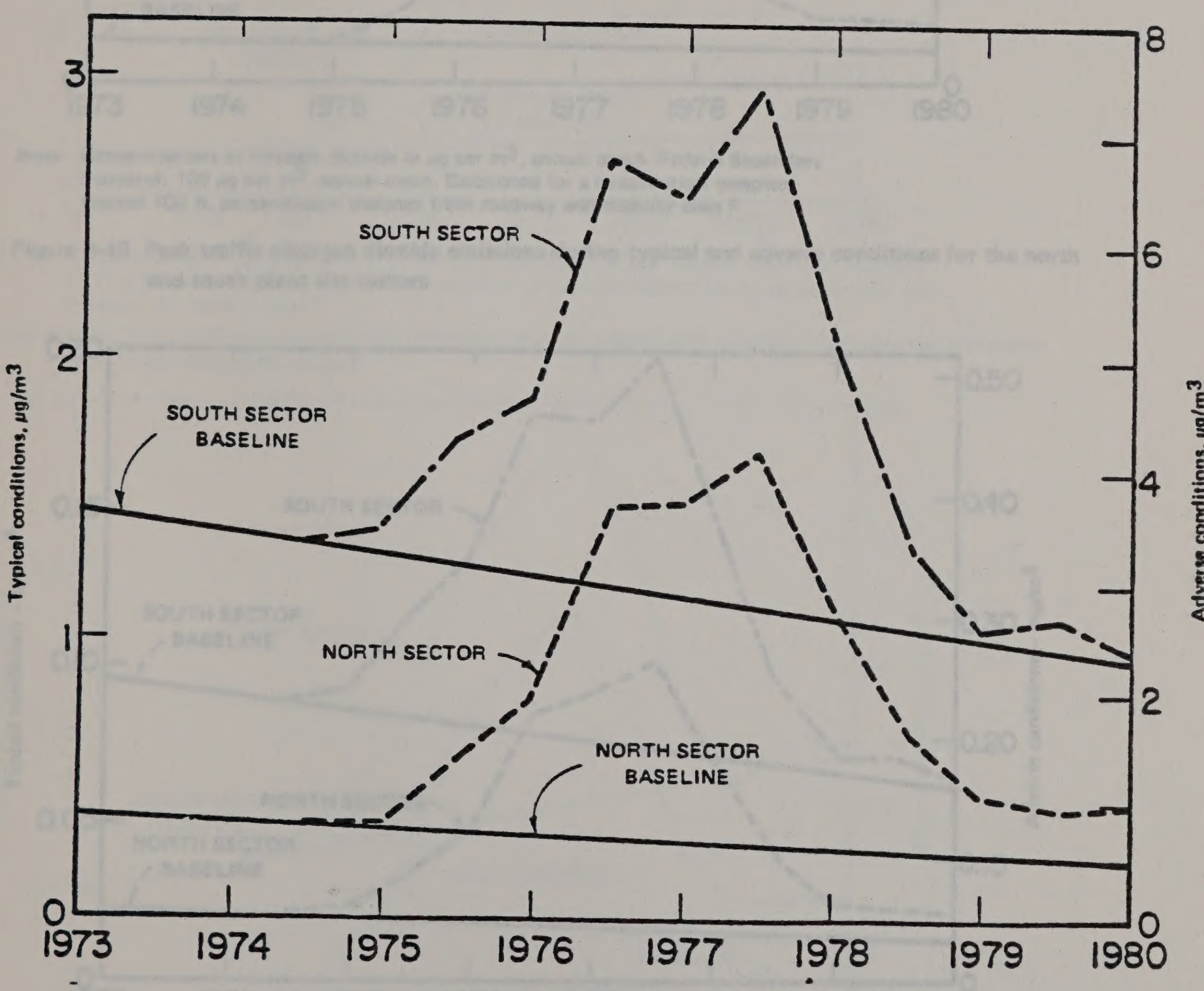


Figure B-47 Peak traffic particulate emissions during typical and adverse conditions for the Douglas sector

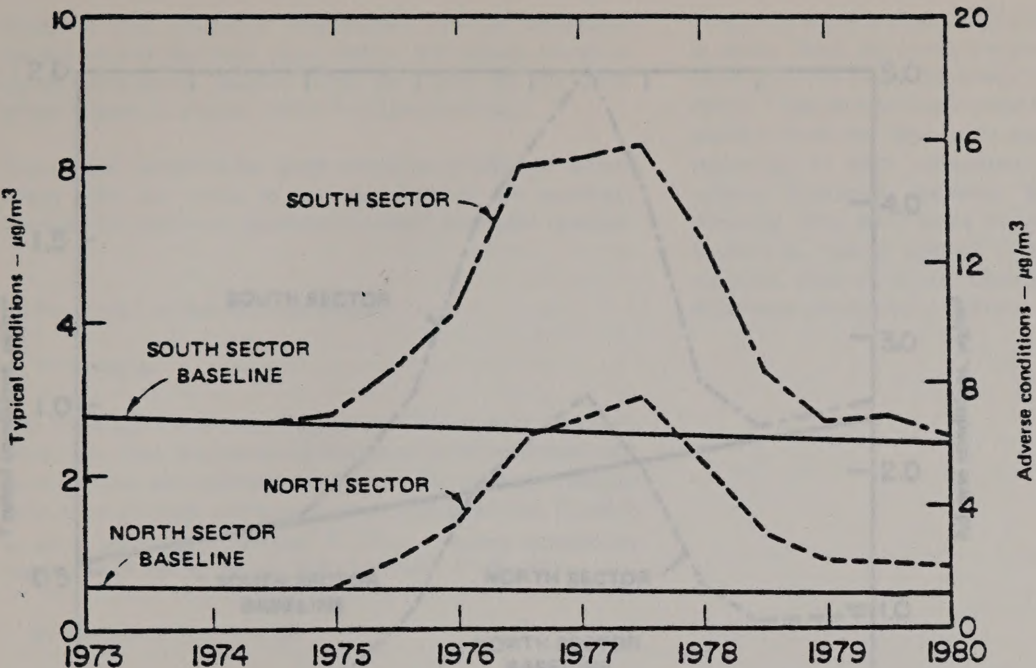
2) Wyoming Highway 59

Microscale computations were also performed for the two sections of highway 59 north of Douglas shown in figures B-48 through B-52. Results indicate that only concentrations of nitrogen dioxide may become significant under the most adverse conditions with the selection of the south plant site. Using "worst case" parameters, the maximum concentrations of nitrogen dioxide computed were 16 percent of the Federal Secondary Standard, based on the south site choice and 8 percent of the standard for the north site. Using the same parameters, hydrocarbon concentrations were 4.8 percent of standard for the south site and 2.8 percent of standard for the north site.



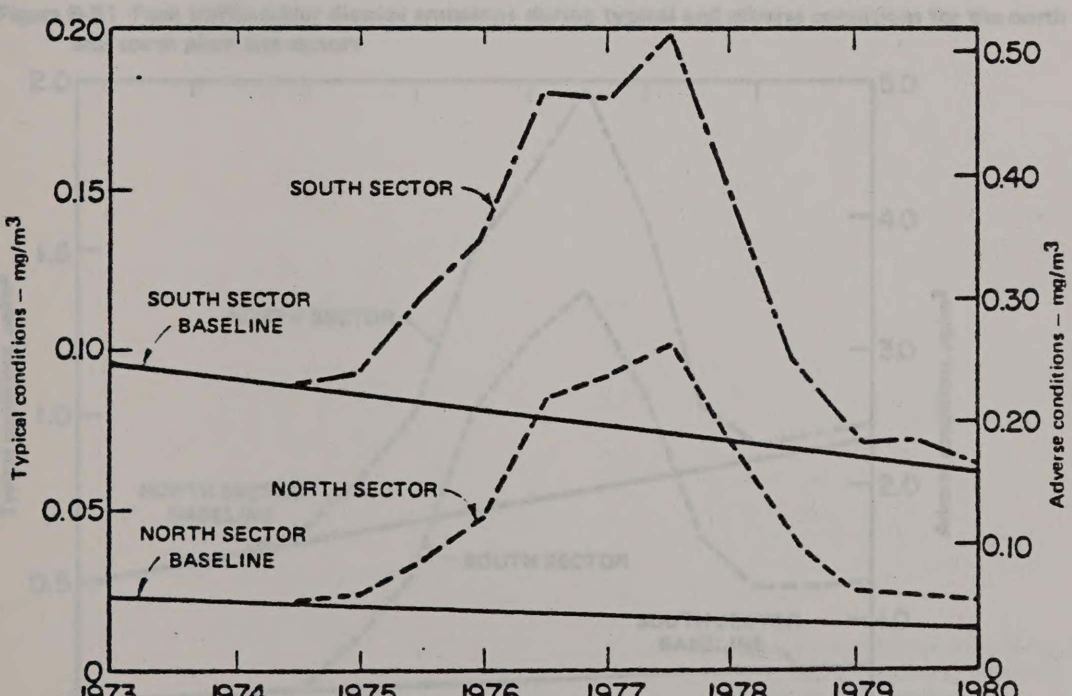
Note: Concentrations of hydrocarbons in µg per m^3, three hour average. Federal Secondary Standard: 160 µg per m^3, three hour average. Calculated for a hypothetical receptor located 100 ft. perpendicular distance from roadway and stability class F.

Figure B-48 Peak traffic hydrocarbon emissions during typical and adverse conditions for the north and south plant site sectors



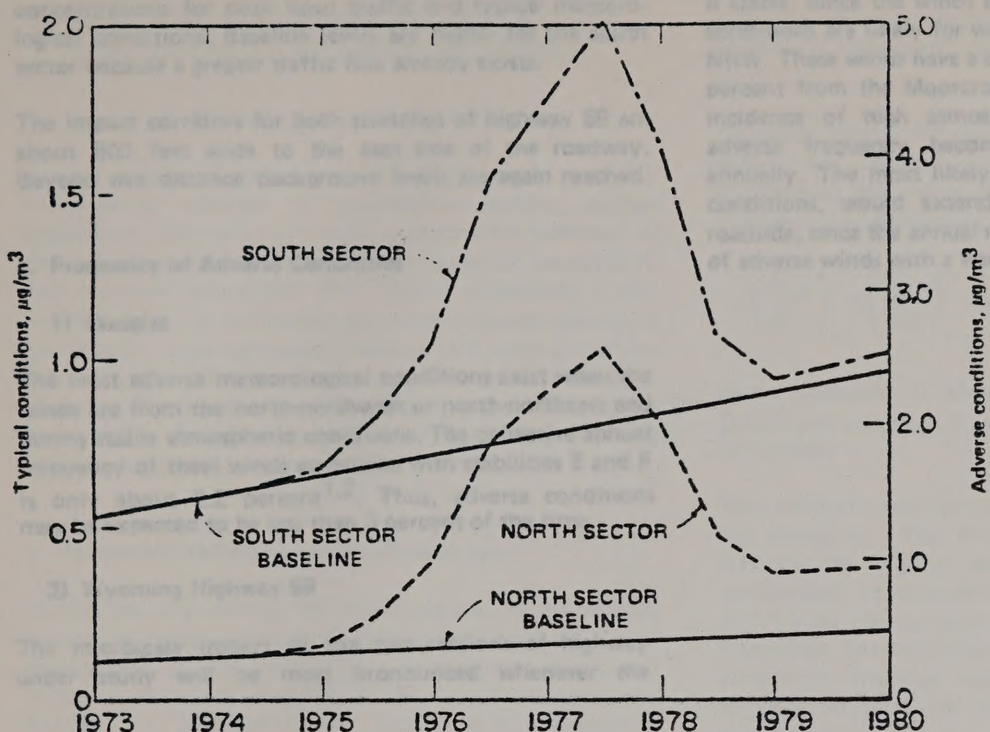
Note: Concentrations of nitrogen dioxide in µg per m^3, annual mean. Federal Secondary Standard: 100 µg per m^3, annual mean. Calculated for a hypothetical receptor located 100 ft. perpendicular distance from roadway and stability class F.

Figure B-49 Peak traffic nitorgen dioxide emissions during typical and adverse conditions for the north and south plant site sectors



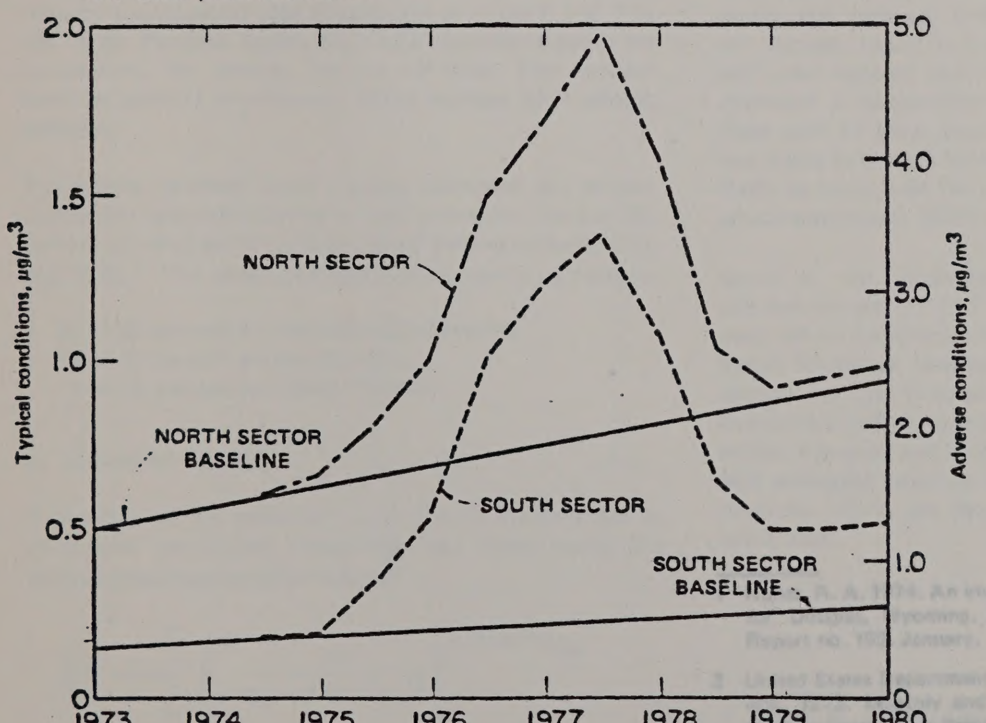
Note: Concentrations of carbon monoxide in milligrams per m^3, one hour average. Federal Secondary Standard: 40 milligrams per m^3, one hour average. Calculated for a hypothetical receptor located 100 ft. perpendicular distance from roadway and stability class F.

Figure B-50 Peak traffic carbon monoxide emissions during typical and adverse conditions for the north and south plant site sectors



Note: Concentrations of sulfur dioxide in μg per m3, three hour average. Federal Secondary Standard: 1300 μg per m3, three hour average. Calculated for a receptor located 100 ft. perpendicular from roadway and stability class F.

Figure B-51 Peak traffic sulfur dioxide emissions during typical and adverse conditions for the north and south plant site sectors



Note: Concentrations of particulates in μg per m3, 24-hour average. Federal Secondary Standard: 150 μg per m3, 24-hour average. Calculated for a receptor located 100 ft. perpendicular distance from roadway and stability class F.

Figure B-52 Peak traffic particulate emissions during typical and adverse conditions for the north and south plant site sectors

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None of the emissions investigated indicate significant concentrations for peak hour traffic and typical meteorological conditions. Baseline levels are higher for the south sector because a greater traffic flux already exists.

The impact corridors for both stretches of highway 59 are about 500 feet wide to the east side of the roadway. Beyond this distance background levels are again reached.

c. Frequency of Adverse Conditions

1) Douglas

The most adverse meteorological conditions exist when the winds are from the north-northwest or north-northeast and during stable atmospheric conditions. The collective annual frequency of these winds associated with stabilities E and F is only about 2.2 percent[1,2]. Thus, adverse conditions may be expected to be less than 3 percent of the time.

2) Wyoming Highway 59

The microscale impact of the two sections of highway under study will be most pronounced whenever the crosswind angle is close to 22.5 degrees and the atmosphere is stable. Since the winds are oriented north-south, adverse conditions are likely for winds from the NNE, SSE, SSW or NNW. These winds have a collective annual frequency of 41 percent from the Moorcroft data. Using 35 percent as the incidence of high atmospheric stabilities, the resulting adverse frequency becomes approximately 14 percent annually. The most likely impact corridor, under adverse conditions, would extend 1100 feet to the east of the roadside, since the annual records[3] show a higher frequency of adverse winds with a westerly component.

1 Nunes, R. A. 1974. An investigation of meteorological dispersion for Douglas, Wyoming. Metronics Associates, Inc. Technical Report no. 192. January.

2 United States Department of Commerce, Environment Data Service. 1973. Monthly and annual wind distribution by Pasquill stability classes, Star Program, Moorcroft, Wyoming. May.

3 California Division of Highways. 1972. Mathematical approach to estimating highway impact on air quality. Prepared in cooperation with the Federal Highway Administration. July.

G. PARTICULATE EMISSION, DEPOSITION, CONCENTRATION, AND SUPPRESSION

1. Airborne Particulate Deposition

Concentrations of particulates initially dispersed in the air tend to be reduced by gravitational settling, surface impaction, electrostatic attraction, absorption (adhesion of particles to a solid surface without chemcial interaction), and chemical interaction. The rate of deposition is also correlated to the immediate ground-level concentration of particulates. Most particulate material will settle out of the atmosphere within a short distance of the source because of their size. Particulates may remain suspended in the air for periods of a few minutes to a week, depending upon the particle size distribution at the time of emission.

a. Particulate Definition and Size Distribution

Particulates are defined by the American Meteorological Society as being any liquid or solid particle suspended in or falling through the atmosphere. Atmospheric particulate matter is described according to the size of the suspended particle. The diameter of the particulate is expressed in microns (millionths of a meter) and they usually range in size from molecular dimensions to about 20μ in diameter. Particles of less than about 0.1μ typically have short lifetimes in the atmosphere due to coagulation with other small particulates. The majority of particulate matter which remains suspended in the atmosphere is in the 0.1 to 10μ size range. Particles greater than 1μ in diameter exist in the atmosphere for shorter periods of time than smaller particles because gravitational forces increase their settling velocity.

Particulates emitted from mining activities are almost exclusively solid dust particles, with a median size (i.e., 50 percent of total particles larger than) ranging between 0.4μ and 1.2μ.[1] The associated size distribution is as follows:

- 25 to 55 percent are less than 0.5μ diameter
- 65 to 92 percent are less than 2μ
- 1 to 10 percent are greater than 5μ

b. Deposition Equations

Estimation of the reduction in dust concentrations due to downwind particulate deposition was made using the following source-depletion factor.[2]

$$\frac{Q'_x}{Q'_0} = \exp\left[\int_0^x \frac{dx}{\sigma_z \exp\,(h^2/2\sigma_z^2)}\right]^{-(2/\pi)^{1/2} v_d/u}$$

equation (1)

Graphical solutions to this relation are given in figure B-53, for a mean wind speed ($\bar{u}$) of 1 meter per second, a deposit velocity (v_d) of 1 centimeter per second and each of Pasquill's stability categories. The mining activities are essentially considered as a ground-level source. (h = 0 meters.)

Depletion factors for other conditions involving other wind speeds and deposition velocities may be obtained by multiplying the value obtained in figure B-53 by the following proportionality conversion:

$$\left(\frac{Q'_x}{Q'_0}\right)_2 = \left(\frac{Q'_x}{Q'_0}\right)_1 \bar{u}_1 v_{d2}/\bar{u}_2 v_{d1} \qquad \text{equation (2)}$$

where subscript 1 refers to the value found on figure B-53[3] and subscript 2 refers to the desired value and new parameters.

Two pertinent conclusions may be drawn from the preceding discussion. The first is that greatest deposition is observed for highest stability. Thus, the unusually high ground-level concentrations associated with high stability and surface sources tend to be counteracted by the greater deposition. Second is that under the most frequent stability conditions (stability class D) over 50 percent of the airborne material will be deposited less than one mile downwind.

c. Estimated Particulate Emissions

The major sources of mine related particulate emissions are overburden removal, drilling and blasting, coal processing, ash disposal, losses from associated transportation facilities, and wind induced dust from disturbed and exposed soils. Although a quantitative estimate of expected emissions from each of these sources is difficult, an approximation was made to present an order of magnitude of the problem. Refer to table B-64 for a summary of these emission values which total nearly 2,000 tons per year.

Some of the assumptions employed in making these calculations are: 1) 0.07 lbs. of particulates are emitted for each ton of overburden removed and there will be handled about 18 million tons per year of overburden; 2) 2 lbs. of particulates are released to the atmosphere per ton of overburden drilled with a total of 14,000 tons per year of drilled material; and 3) 0.05 lbs. of particulates per ton of coal processed based on a rate of 900 tons per hour, 4 coal breakers, 12 hr. per day, 365 days per year and a 5 day work week.

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1 Green, H. L. and Lane, W. R. 1964. Particle clouds, dusts, smokes, mists. Second edition.

2 United States Atomic Energy Commission. 1971. Meteorology and atomic energy. 1968.

3 Estimated from EPA emission factors on concrete batching.

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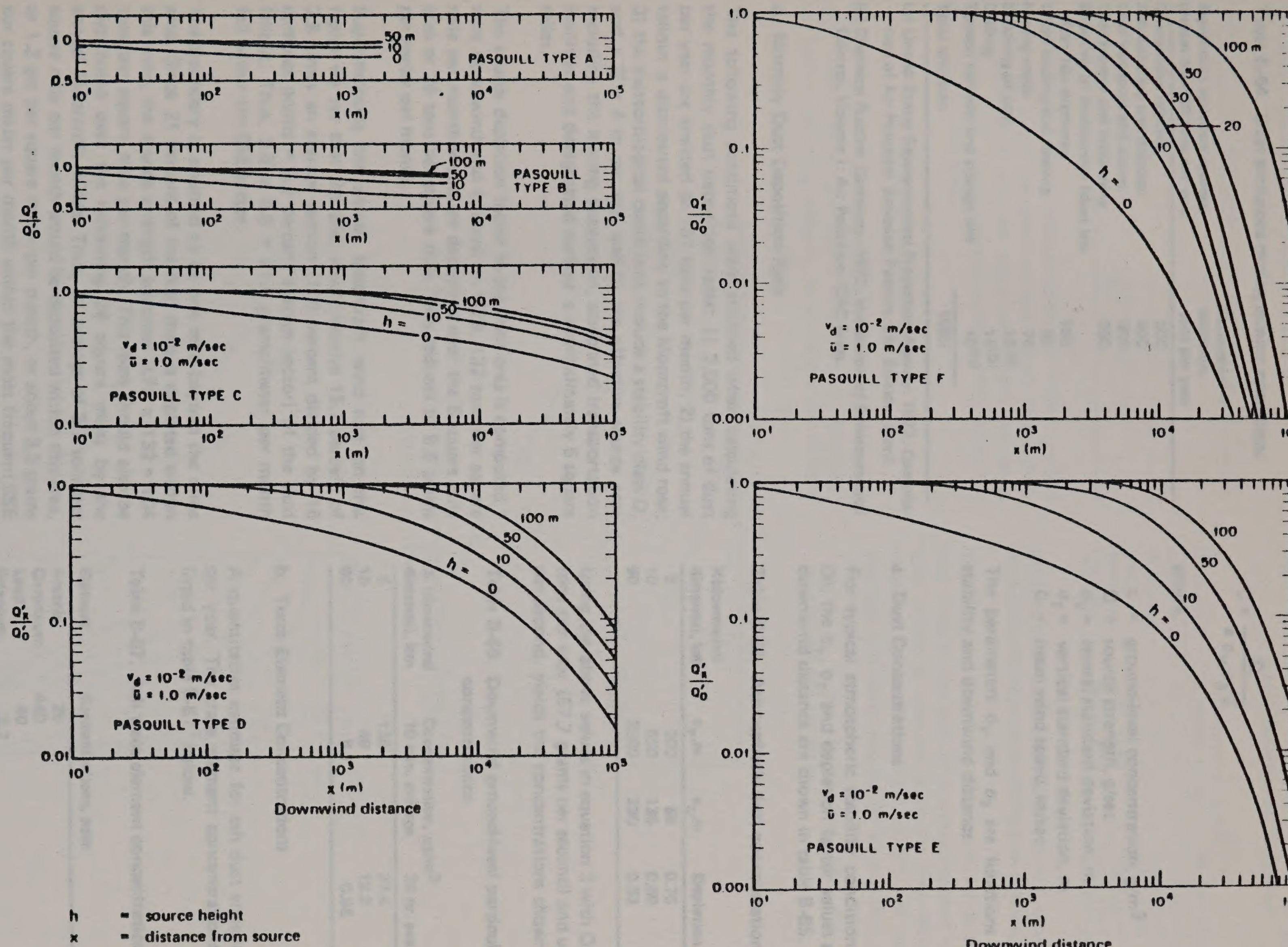


h = source height
x = distance from source
Q'_o = source strength
Q'_x = effective source strength at distance x

Figure B-53 Particulate source depletion factors as a function of downwind distance, source height, and stability

Table B-64. Dust emissions during mining operations

Significant emission sources greater than 20 tons per year	Estimated[(a)] emission, tons per year
Overburden removal	600
Ash handling and disposal	400
Coal transport and sizing	300
Coal storage and reclaiming	250
Shooting of overburden (dust less than 10μ diameter)	150
Local loading and hauling	85
Mining roads	70
Shooting of coal	16[(b)]
Drilling	14[(b)]
Topsoil removal and storage pile	10[(b)]
Total emission	1895

(a) United States Environmental Protection Agency. 1973. Compilation of Air Pollutant Emission Factors. 2nd Edition. April.

(b) Chemical Rubber Company. 1972. Handbook of Environmental Control, Volume I: Air Pollution. CRC Press.

d. Monthly Dust Deposition Rate

The following conditions were assumed when calculating the monthly dust deposition rates: 1) 2,000 tons of dust per year are emitted or 167 tons per month; 2) the annual fallout is distributed according to the Moorcroft wind rose; 3) the meteorological conditions include a stability class D, and a $\overline{u}$ = 4 m per sec; and 5) the effective source area including the mining excavation, associated transportation facilities and devegetated surface is approximately 5 square miles.

The source depletion factor in the mine area is computed 1 mile downwind and is equal to 0.79. 132 tons per square mile per month would be deposited over the 5 square mile area or 25 tons per square mile. This reduces to 8.6 grams per meter per month.

Superimposing the annual Moorcroft wind rose on this figure we see that the SSE would receive 15.7 percent of 2.5 times an average section (100 percent divided by 16 compass points = 6.2 percent average sector) of the dust fallout. Thus, 2.5 x 8.6 = 21.5 grams/meter per month fall within the SSE sector.

The boundary is assumed to be one mile beyond the mine area. Since 21 percent of the dust mass is depleted within this mile, the source strength becomes 0.79 x 132 = 104 tons per square mile per month. This mass should also be distributed over the remaining 28 square miles by the annual Moorcroft winds. Thus, an average of 3.7 tons per square mile per month would be deposited within this area, or 1.3 gm per square meter per month, or about 3.3 grams per square meter per month within the most frequent SSE sector.

2. Ground-Level Particulate Concentrations

For a ground-level source, downwind particulate concentration can be described by the following diffusion equation:

$$C = \frac{Q}{\pi \sigma_y \sigma_z \overline{u}} \qquad \text{equation (3)}$$

where,

c = ground-level concentration, g/m^3
Q = source strength, g/sec
σ_y = lateral standard deviation, m
σ_z = vertical standard deviation, m
$\overline{u}$ = mean wind speed, m/sec

The parameters σ_y and σ_z are functions of atmospheric stability and downwind distance.

a. Dust Concentrations

For typical atmospheric stability conditions (neutral class D), the σ_y, σ_z, and depletion factor values as a function of downwind distance are shown in table B-65.

Table B-65. Atmospheric dust concentration parameters

X(downwind distance), km	σ_y,m	σ_z,m	Depletion factor
5	300	88	0.75
10	550	135	0.69
50	2200	330	0.53

Using the above values in equation 3 with Q equalling 2000 tons per year (57.7 grams per second) and u being 5 meters per second, yields the concentrations shown in table B-66.

Table B-66. Downwind ground-level particulate concentrations

X (downwind distance), km	Concentration, μg/m^3 10 min. average	24 hr. average
5	139	37.4
10	49	12.2
50	5.1	0.96

b. Trace Element Concentrations

A quantitative estimate for ash dust emissions is 400 tons per year. The trace element concentrations in the ash are listed in table B-67[1] below.

Table B-67. Ash trace element concentrations

Element	Concentrations, ppm
Arsenic	26
Chromium	440
Lead	40
Selenium	2.2
Fluorine	55

Values of corresponding trace element emission strengths are shown in table B-68.

1 Accu-Labs Research, Inc., Wheat Ridge, Colorado.

Table B-68. Trace element emission strengths

Element	Q, lbs. per year	Q, grams per sec.
Arsenic	20.8	3.0×10^{-4}
Chromium	352	5.1×10^{-3}
Lead	32	4.6×10^{-4}
Selenium	1.8	2.6×10^{-5}
Fluorine	44	6.3×10^{-4}
Total	450.6	65.2×10^{-4}

For stability D and a downwind distance of 5 km; $\sigma_y = 300$ m, $\sigma_z = 89$ m, and the same depletion factor equals 0.75. Using equations 3 with the above parameters and values from table B-66, the downwind trace element concentrations listed in table B-69.

Table B-69. Ground-level trace element concentrations 5 km downwind of the source

Element	Concentration, $\mu g/m^3$ 10 minute average	24 hour average
Arsenic	7.2×10^{-4}	1.9×10^{-4}
Chromium	12.2×10^{-3}	3.3×10^{-3}
Lead	11.0×10^{-4}	3.0×10^{-4}
Selenium	6.2×10^{-5}	1.6×10^{-5}
Fluorine	15.0×10^{-4}	4.0×10^{-4}

3. Dust Suppression by Sprays

A major form of suppressing mining dust is by the use of water sprays. Sprays are used to either wet or immobilize dust before becoming airborne, or to remove the airborne particles from suspension. High pressure water sprays are a most efficient means of airborne dust removal.

The collection efficiency (E%) is defined as the portion of dust lying in the path of a sprayed droplet which collides with it and is removed from the dust cloud. The total particles removed per unit volume of water sprayed increases with spray velocity for all dust sizes. Figure B-54[1]

1 Walton, W. H. and Woolcock, A., 1960. The suppression of airborne dust by water spray.

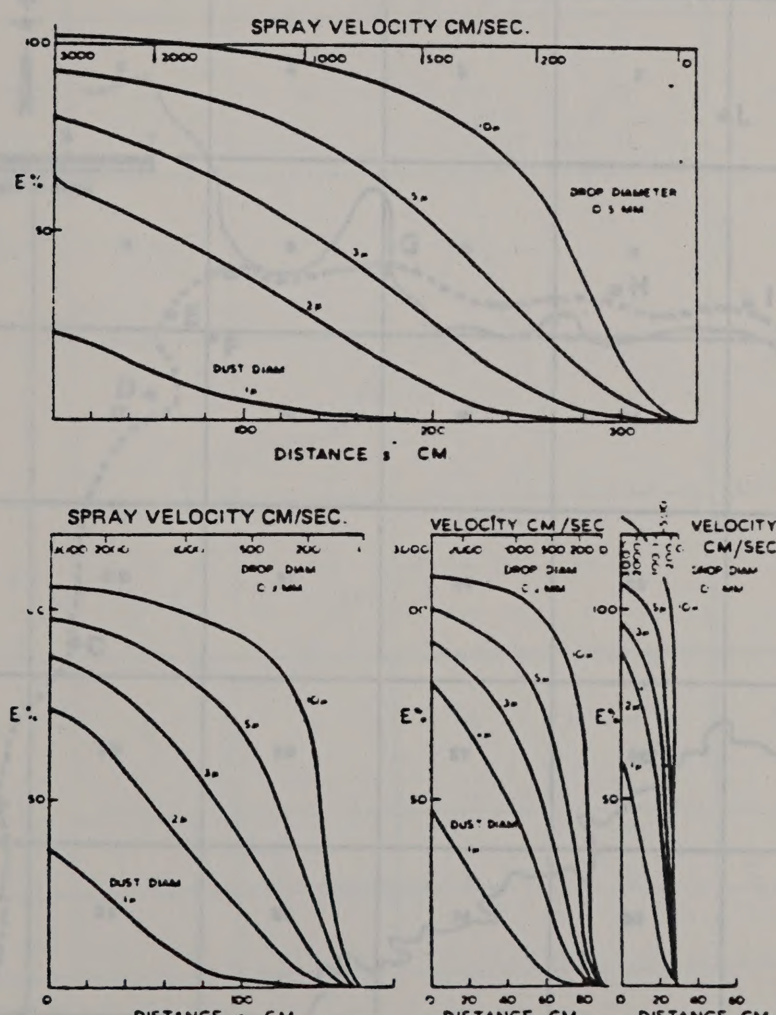


Figure B-54 Dust collection efficiency of water sprays

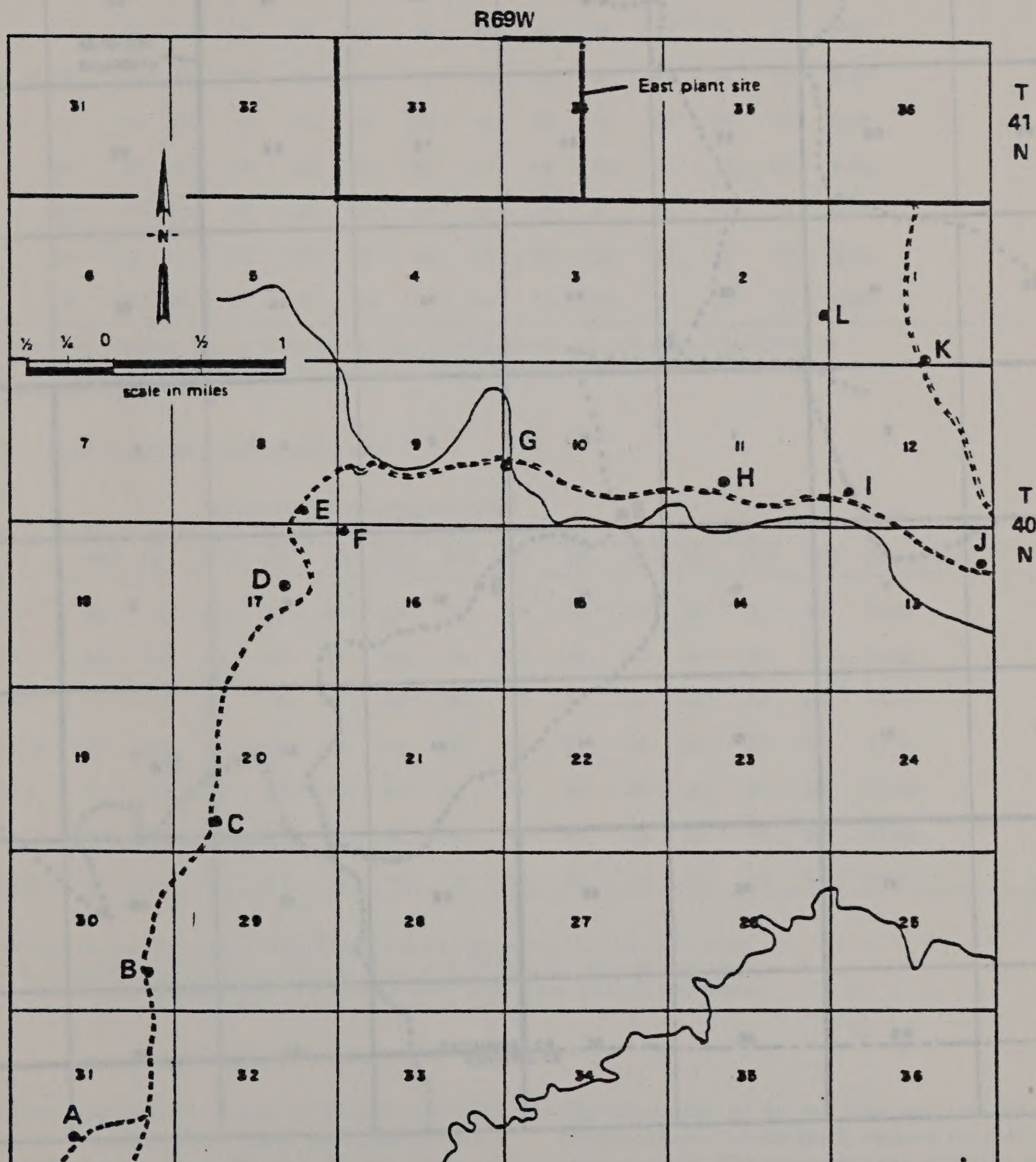
illustrates the collection efficiencies of various spray drop diameters as a function of coal dust sizes ranging from 1 to 5 microns.

It appears to be feasible to achieve a 90 percent removal of respirable coal dust in the size range 1 to 5 microns diameter at a water consumption rate of about 5 to 10 gallons per 1000 cubic feet of air treated.[1] Application of this might be found in regions of dust production including the crushing, screening, drilling and loading operations.

H. NOISE SURVEY

Ambient noise measurements were recorded in the vicinity of the proposed coal mine (Rochelle mine site) and gasification plant (east site) to aid in evaluating the existing noise environment. These sound level recordings were conducted on June 14-15, 1973, at the selected sampling points shown in figures B-55 and B-56. Actual field readings are presented in tables B-70 and B-71.

1 Walton, W. H. and Woolcock, A. 1960. The suppression of airborne dust by water spray.



Note: Noise sampling points are designated A through L

Figure B-55 Noise survey sampling points adjacent to east plant site

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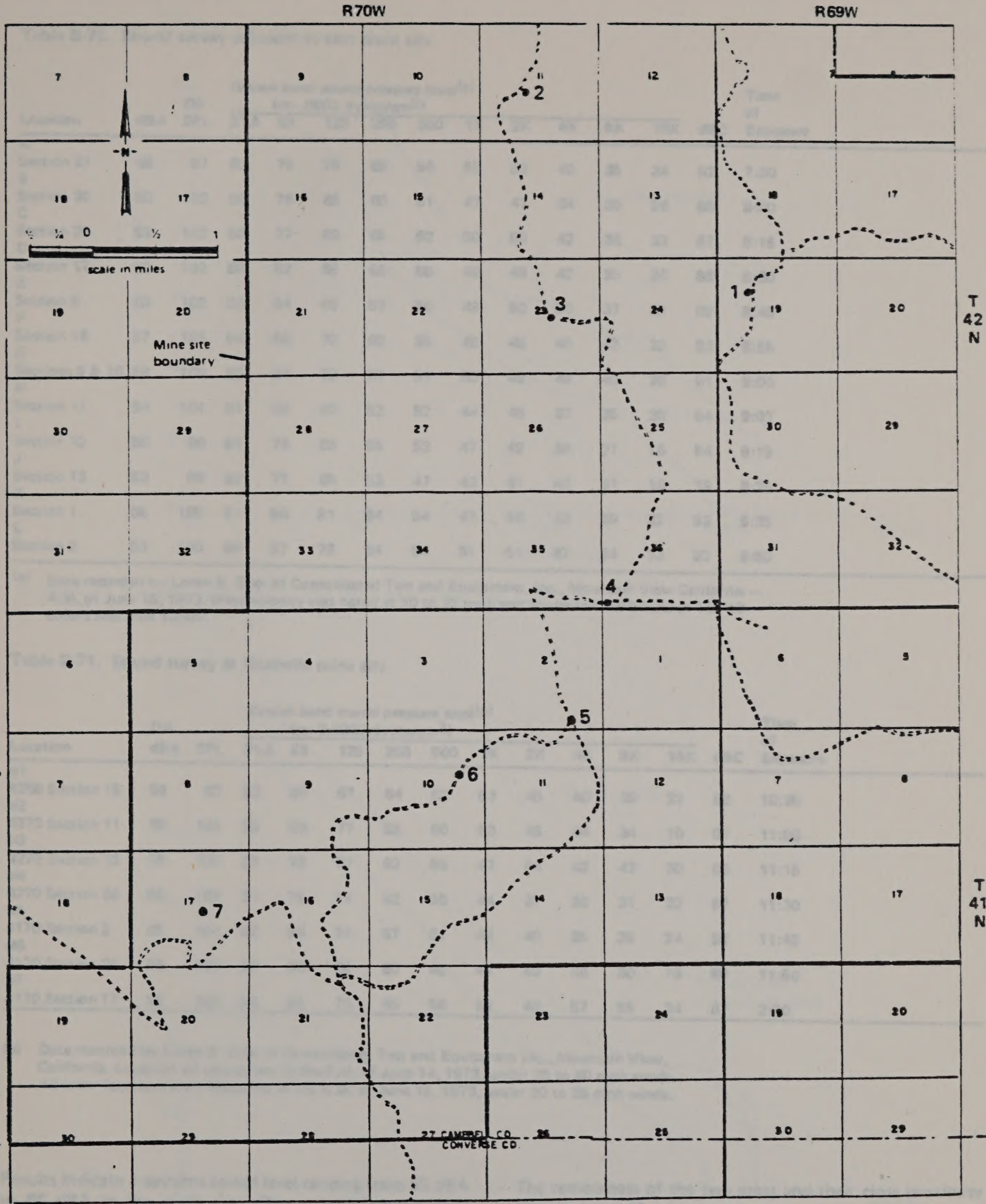

Note: Noise sampling points are designated 1 through 7

Figure B-56 Noise survey sampling points at Rochelle mine site

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Table B-70. Sound survey adjacent to east plant site

Location	dBA	OS SPL	Octave band sound pressure level[a] (re: .0002 dynes/cm^2) 31.5	63	125	250	500	1K	2K	4K	8K	16K	dBC	Time of Exposure
A Section 31	66	97	88	75	78	68	56	55	52	40	35	34	92	7:30
B Section 30	63	102	88	76	68	60	51	47	47	34	30	26	88	8:00
C Section 20	58	102	90	77	69	65	52	50	50	42	36	33	87	8:15
D Section 17	62	102	89	82	68	66	50	49	49	42	35	26	88	8:30
E Section 8	60	102	86	84	68	57	50	49	50	50	37	28	88	8:45
F Section 16	57	103	94	88	79	68	55	48	48	45	42	32	93	8:55
G Sections 9 & 10	59	100	86	84	72	55	51	50	48	49	40	36	91	9:00
H Section 11	54	104	81	80	60	52	52	44	45	37	35	20	84	9:07
I Section 12	55	99	81	76	65	55	52	47	42	38	27	16	84	9:15
J Section 13	53	99	82	77	65	53	47	43	41	42	37	16	78	9:25
K Section 1	66	105	91	86	81	64	54	47	46	42	39	32	93	9:35
L Section 2	56	100	89	87	76	64	54	51	51	47	34	33	82	9:50

(a) Data recorded by Loren B. Eller of Consolidated Test and Equipment, Inc., Mountain View California — A.M. of June 15, 1973. Wind velocity was noted at 20 to 25 mph and equipment calibrated at 125 dB before and after survey.

Table B-71. Sound survey at Rochelle mine site

Location	OA dBA	SPL	Octave band sound pressure level[a] (re: 0.0002 dynes/cm^2) 31.5	63	125	250	500	1K	2K	4K	8K	16K	dBC	Time of Exposure
#1 4269 Section 19	59	97	83	80	67	64	60	53	45	40	39	22	82	10:35
#2 4270 Section 11	62	101	88	83	77	68	60	53	45	44	34	19	91	11:00
#3 4270 Section 23	58	102	87	78	67	62	58	47	44	42	43	30	88	11:15
#4 4270 Section 36	59	103	91	79	74	62	55	44	37	39	31	32	87	11:30
#5 4170 Section 2	65	104	92	84	74	57	51	44	40	35	29	24	92	11:45
#6 4170 Section 21	58	104	88	80	68	60	48	44	40	36	30	19	88	11:50
#7 4170 Section 17	66	108	90	88	76	65	56	52	49	57	55	34	87	2:00

(a) Data recorded by Loren B. Eller of Consolidated Test and Equipment Inc., Mountain View, California. Location #7 was survey in the P.M. of June 14, 1973, under 35 to 40 mph winds. All other locations were measured in the A.M. of June 15, 1973, under 20 to 25 mph winds.

Results indicate a daytime sound level ranging from 53 dBA to 66 dBA in the study area. These measurements were generally taken during 20 to 25 mph winds which are considered typical over eastern Wyoming. Most of the higher amplitudes were found in the low frequencies which is a common characteristic of winds. There are no stationary noise sources presently in the areas surveyed.

The remoteness of the two areas and their close proximity to each other (3 miles apart) account for their similar noise characteristics. The recorded noise levels for the east plant site area and mine area are graphically displayed in figures B-57 and B-58, respectively. Note the increase in mine measured noise at the higher frequencies associated with higher velocity winds (35 to 40 mph).

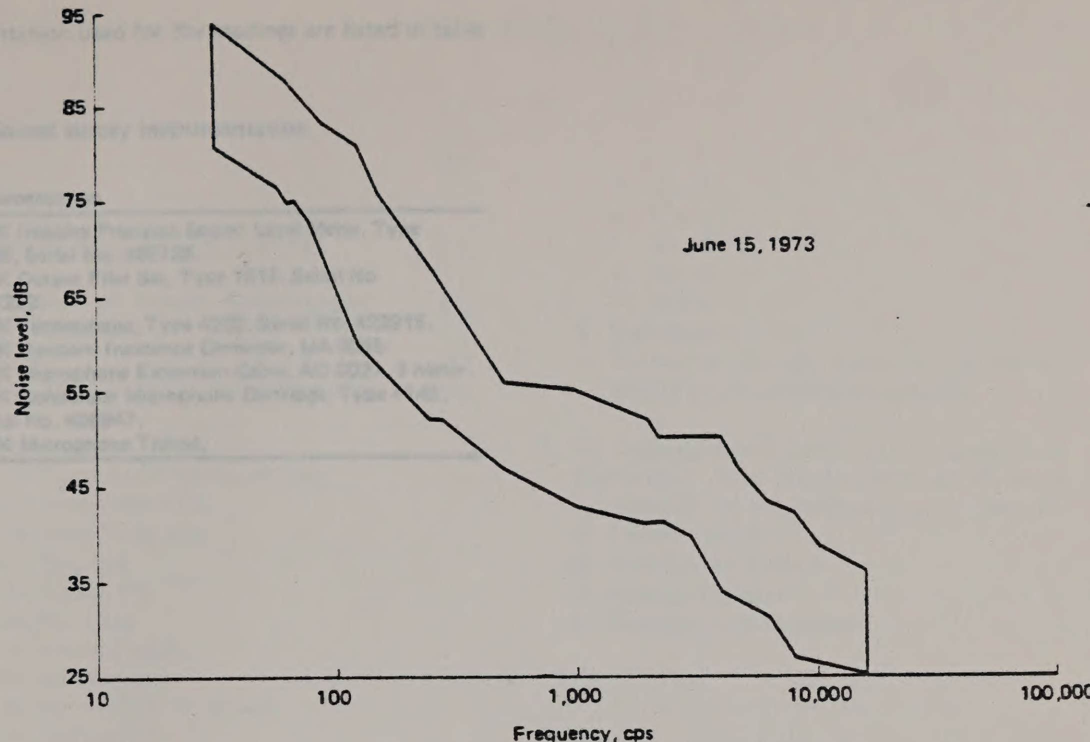

Figure B-57 Envelope of recorded noise levels adjacent to east plant site

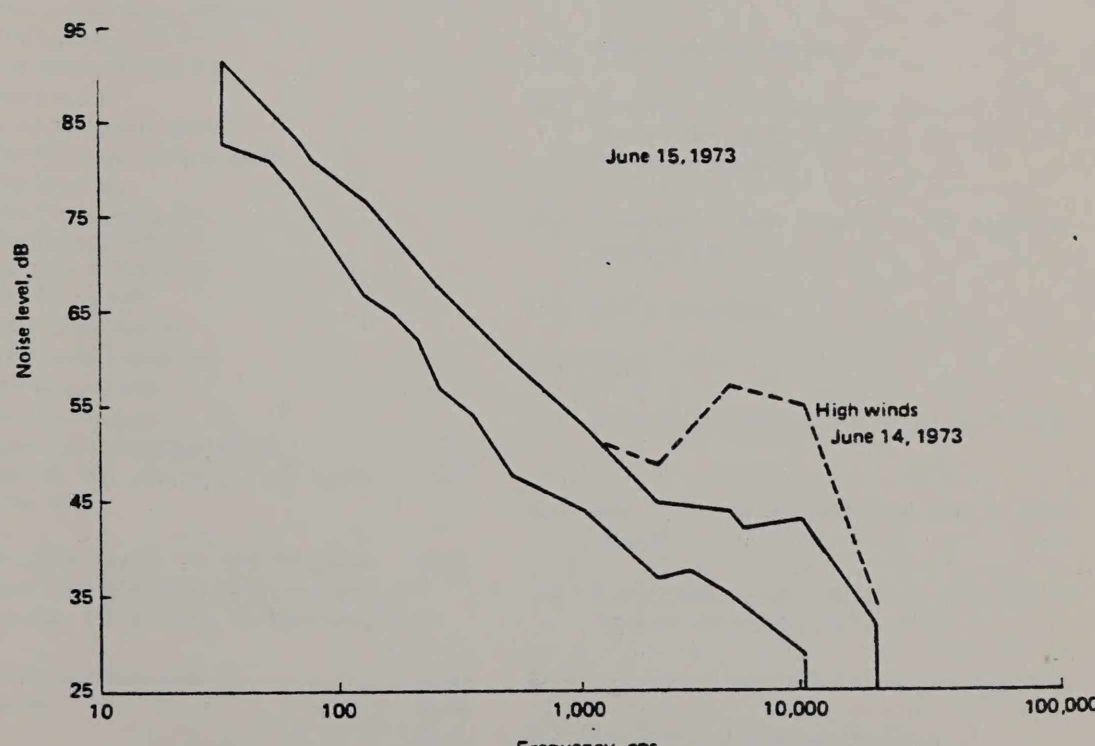

Figure B-58 Envelope of recorded noise levels at Rochelle mine area

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The instrumentation used for the readings are listed in table B-72.

Table B-72. Sound survey instrumentation

Item	Instrumentation
1	B & K Impulse Precision Sound Level Meter, Type 2209, Serial No. 405735.
2	B & K Octave Filer Set, Type 1613, Serial No. 405222.
3	B & K Pistonphone, Type 4220, Serial No. 422915.
4	B & K Random Incidence Corrector, UA 0055.
5	B & K Microphone Extension Cable, AO 0027, 3 meter.
6	B & K Condensor Microphone Cartridge, Type 4145, Serial No. 406947.
7	B & K Microphone Tripod.

APPENDIX C-3. PLANT SITE STUDIES, ARCHAEOLOGY

List of Figures

A. INTRODUCTION

This appendix contains: 1) a letter from George Frison on the significance of the Peabody Coal land (Rochelle Coal Company) in Campbell County, and 2) three reports on the archaeological significance of the area. The first report is a general statewide overview while the second report addresses the proposed reservoir site and the south and east plant sites. The third report addresses the north plant site.

B. STATEMENT OF ARCHAEOLOGICAL SIGNIFICANCE

THE UNIVERSITY OF WYOMING
DEPARTMENT OF ANTHROPOLOGY
ARTS AND SCIENCES BUILDING
UNIVERSITY STATION, BOX 3431
LARAMIE, WYOMING 82071

Febraury 28, 1974

Mr. Leonard G. Shearer
Division Engineer
12075 E. 45th Ave.
Denver, Colorado 80239

Dear Mr. Shearer:

This letter is to clarify the situation regarding archeological surveys on Peabody Coal land in Campbell County, Wyoming. We will do the surveys, weather and scheduling permitting. From our literature surveys, the area contains no known archeological sites. From previous archeological work in that area of Wyoming, however, we know that the Powder River Basin as a whole is a rich archeological area.

It has been the pattern of prehistoric occupations in Wyoming that the most intensive prehistoric occupations are to be found in areas of greatest topographic relief. Our postulations at this time are that these kinds of areas provided the best conditions for economic resources as well as living conditions. The open and relatively flat areas of the Powder River Basin on the basis of present evidence, demonstrate less intense use and consequently few archeological manifestations than other areas.

The Peabody Coal areas as presently defined in Campbell County are in part of the relatively open areas and we do not expect to find intensive prehistoric occupation there. However, we do feel that a survey is necessary to determine the exact nature of prehistoric activity since all evidence is important and must be evaluated before the complete record of prehistoric cultural systems on the Plains can be realized.

Sincerely,

George C. Frison, Head
Department of Anthropology

GCF:lf

C. A BRIEF SUMMARY OF KNOWN ARCHAEOLOGICAL RESOURCES IN WYOMING

Prepared by

George M. Zeimens
Michael Wilson
Tom Larson
Mark Miller
David McQuire

Department of Anthropology
University of Wyoming
Laramie, Wyoming

1. Introduction

This subsection has been reprinted verbatim from the report "A Brief Summary of Known Archaeological Resources in Wyoming," prepared by the Department of Anthropology, University of Wyoming, Laramie, Wyoming.

With the advent of the "energy crisis" and accelerated mineral exploration and energy development in Wyoming, interest in archaeological resources has increased. Government agencies, industry, environmental protection groups, archaeologists, and a large part of the populace are for their various reasons concerned about the impact of energy development and related projects upon archaeological resources in affected areas. Those interested in the prehistoric past fear the wanton destruction of valuable data reminiscent of large-scale public work projects in the past. Industrial concerns fear they may unwittingly destroy something and be faced with the wrath of the conservationist. These fears, whatever their basis may be, stem from impending losses to the tremendous amount of archaeological data known to exist in Wyoming.

To familiarize interested parties with known archaeological resources, current research projects, and the archaeological potential of various areas, a compendium of Wyoming archaeology is badly needed. The purpose of this paper is to compile information pertinent to such a treatise and hopefully to formulate a statement concerning the potential and need for increased archaeological studies.

Wyoming is actually peripheral to three large archaeological cultural areas: The Great Basin to the southwest, the Plateau to the northwest, and the Northwestern Plains to the east which includes the largest portion of the state (Wedel 1969:23). These are arbitrary boundaries and are based upon the traditional ethnographic culture area concept (Willey 1966:5-7). These boundaries are vague at best and do not negate interaction and movement from one area to another, but only constitute a frame of reference for dealing with archaeological phenomena.

However, for purposes of this literature survey, it is more convenient to divide the state into four study areas (fig. C-1). These are general areas and do not delineate cultural

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developments, topographic features, or ecological zones. They are arbitrary areas but useful here since they more or less coincide with areas to be exploited for mineral resources.

The chronological framework for the Northwestern Plains that applies to all four study areas was developed by William Mulloy (Mulloy 1958:126-140). Some gaps have been filled since his original work but the sequence he established is still used today. On the basis of data from several stratified sites he developed four broad time periods: the Early Prehistoric or Paleo Period from the earliest arrival of man to 5000 B.C., the Altithermal 5000 B.C. to 2500 B.C., the Early Middle and Late Middle Prehistoric 2500 B.C. to A.D. 500, Late Prehistoric A.D. 500 to Historic. Like the spatial boundaries, these chronological boundaries are vague approximations and are more useful than real.

All resources for this research can be found at the University of Wyoming. This paper is a product of a literature survey and can in no way be considered an inventory of all archaeological resources in Wyoming.

2. Study Area Number One: A Descriptive Analysis

Briefly stated, the western boundary of this area runs from the Montana border south down the Big Horn divide to Waltman. The southern boundary is U.S. Highway 26 and 20 from Waltman to Casper and the North Platte River from Casper to the Nebraska state line. The eastern boundary is the Wyoming-Nebraska and Wyoming-South Dakota state lines. The northern boundary is the Montana-Wyoming state line. The area is comprised of the eastern slope of the Big Horns, the Black Hills, drainages of the

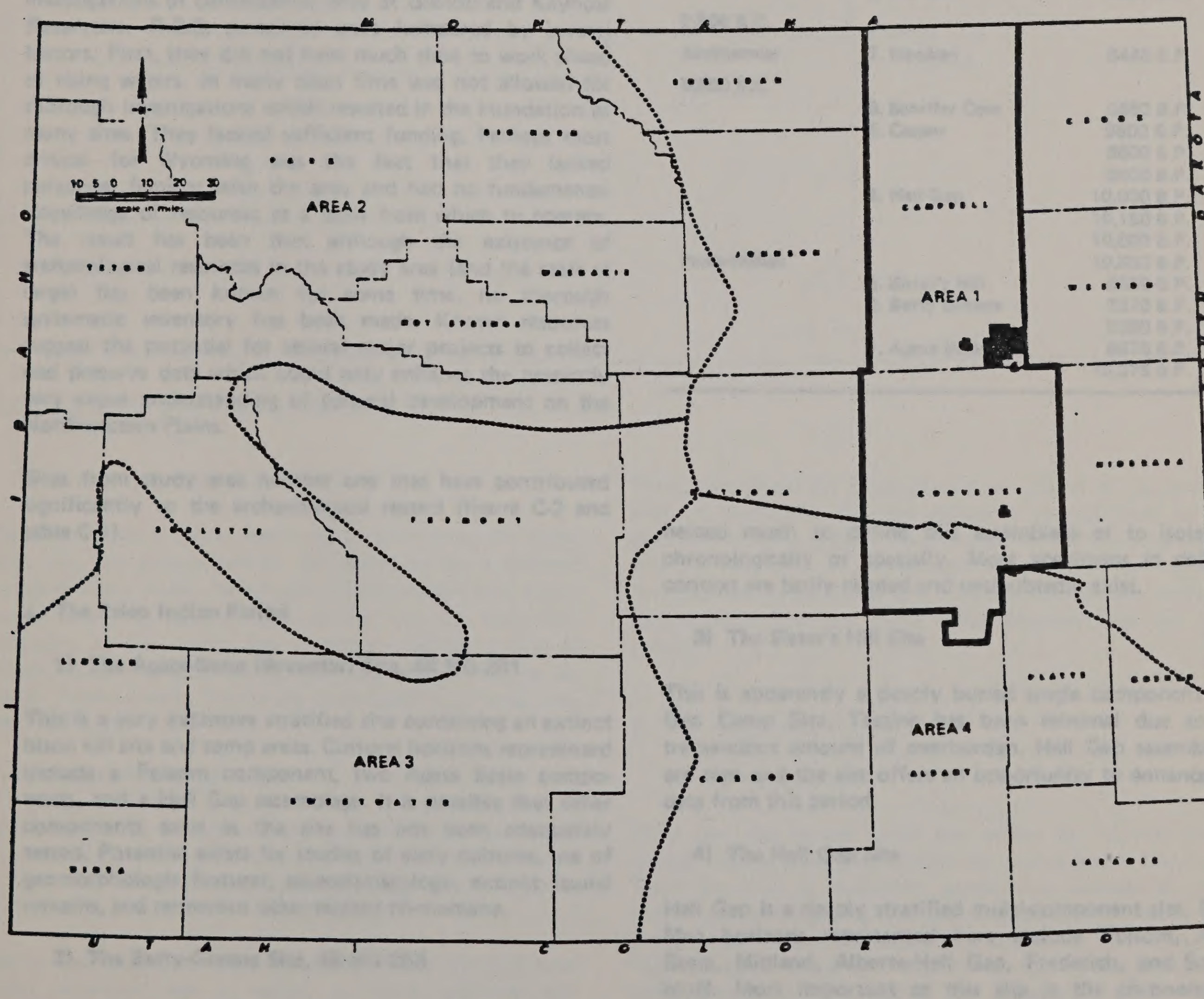

Figure C-1 Study area

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Powder, Tongue, Belle Fourche, Cheyenne, and Little Missouri Rivers, and the northern tributaries of the North Platte River. Historically, the area was inhabited by the Crow, Cheyenne, Oglala and Brule Sioux, Blackfeet, Arapahoe, and Shoshoni (Frison 1973:170-173). Most of these people were forced into the area during the late Prehistoric Period due to expansion of White settlements in the East. It is difficult to extend historically documented tribal affiliations back beyond the Historic Period. In most cases cultures recorded at contact time had already changed extensively due to Anglo influences and the acquisition of the horse.

Early archaeological investigations in the area, as in the entire state, were spotty. Excursions through the area by Renaud (Renaud 1931) and Sowers (Sowers 1941) were very superficial and although they reported locating several sites, no systematic investigations or interpretations resulted. Since World War II several reservoir sites in the study area have been investigated by the River Basin Survey in conjunction with the Missouri River Project but led to investigations of consequence only at Glendo and Keyhole Reservoirs. R.B.S. personnel were hampered by several factors. First, they did not have much time to work ahead of rising waters. In many cases time was not allowed for thorough investigations which resulted in the inundation of many sites. They lacked sufficient funding. Perhaps most critical for Wyoming was the fact that they lacked personnel familiar with the area and had no fundamental knowledge of resources as a basis from which to operate. The result has been that although the existence of archaeological resources in the study area (and the state at large) has been known for some time, no thorough systematic inventory has been made. Known resources suggest the potential for several major projects to collect and preserve data which could only enhance the presently very vague understanding of cultural development on the Northwestern Plains.

Sites from study area number one that have contributed significantly to the archaeological record (figure C-2 and table C-1).

a. The Paleo Indian Period

1) The Agate-Basin (Brewster) Site, 48 NO 301

This is a very extensive stratified site containing an extinct bison kill site and camp areas. Cultural horizons represented include a Folsom component, two Agate Basin components, and a Hell Gap assemblage. It is possible that other components exist as the site has not been adequately tested. Potential exists for studies of early cultures, use of geomorphologic features, paleoclimatology, extinct faunal remains, and numerous other related phenomena.

2) The Betty-Greene Site, 48 NO 203

Artifacts from this site represent a complex which is still very obscure. Similar materials from Hell Gap have not helped much to define this assemblage or to isolate it chronologically or spatially. More specimens in definite context are badly needed and undoubtedly exist.

Table C-1. Chronological sequence of dated sites in the study area

Period	Site	Radiocarbon date
(Historic)		
	24. Foss Thomas	500 B.P.
	23. Billy Creek	–
	22. PK Burial	–
Late Prehistoric	21. Medicine Creek	–
	20. Big Goose	450 B.P.
	19. Piney Creek	–
	18. Vore	200 B.P.
	17. Glenrock	250 B.P.
A.D. 500		
	16. Lee	1500 B.P.
	15. Sweem-Taylor	–
	14. Lissolo Cave	–
	13. Glendo	–
	12. Ruby	A.D. 300
Middle Period	11. Mavrakis-Bentzen-Roberts	2600 B.P.
	10. Powder River	3220 B.P.
	9. Powers-Yonkee	4450 B.P.
	8. McKean	3287 B.P.
2,500 B.C.		
Altithermal	7. Hawken	6440 B.P.
5,000 B.C.		
	6. Schiffer Cave	8450 B.P.
	5. Casper	9800 B.P.
		8600 B.P.
		8600 B.P.
	4. Hell Gap	10,000 B.P.
		10,150 B.P.
		10,600 B.P.
Paleo-Indian		10,850 B.P.
	3. Sister's Hill	9650 B.P.
	2. Betty Greene	7870 B.P.
		9350 B.P.
	1. Agate Basin	9970 B.P.
		10,375 B.P.

3) The Sister's Hill Site

This is apparently a deeply buried single component Hell Gap Camp Site. Testing has been minimal due to the tremendous amount of overburden. Hell Gap assemblages are rare and the site offers an opportunity to enhance the data from this period.

4) The Hell Gap Site

Hell Gap is a deeply stratified multi-component site. Early Man horizons represented here include Folsom, Agate Basin, Midland, Alberta-Hell Gap, Frederich, and Scottsbluff. Most important at this site is the chronological sequence of well stratified components. Unfortunately, findings here have never been fully reported.

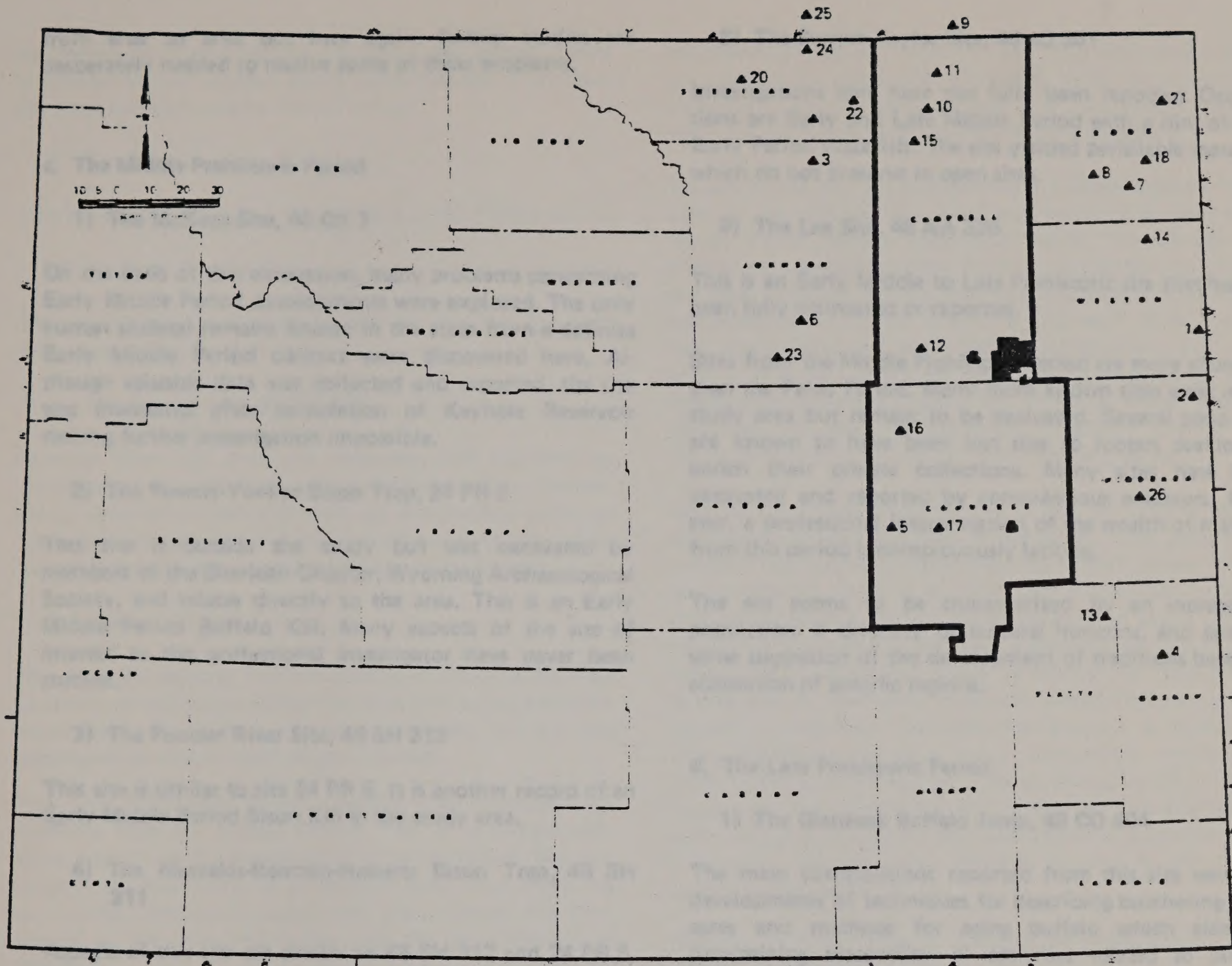

Figure C-2 Major sites in study area

5) The Casper Site, 48 NA 304

The Casper Site is one of two Paleo-Indian sites in the study area that are represented in the literature by a detailed comprehensive report based upon explicit laboratory analyses of recovered material. The site is a Hell Gap bison kill. Included in the report are important considerations of extinct bison remains, use of geomorphologic features for bison procurement, butchering techniques and tools, and lithic analysis.

6) Schiffer Cave, 48 JO 319

Schiffer Cave is a single component Late Paleo-Period site and has been comprehensively documented in the literature. It contributed much to a time period about which only scanty information is available.

Early Period sites are relatively scarce. Many probably have been destroyed due to natural erosional processes and some, such as Sister's Hill, are undoubtedly deeply buried and not apparent on the surface. Artifacts from the Early Period are found on the surface in all sectors of the study area. It is evident that the period is characterized by a diversity of early culture horizons, as reflected in projectile point types, with an orientation toward the hunting of now-extinct forms of buffalo. Further studies are needed before generalizations about early developments can be valid.

b. The Altithermal Period

1) The Hawken Site

Only one site in the study area seems to fall into this period. This is a kill site containing extinct bison. Material from this site is presently undergoing analysis at the University of Wyoming and promises to yield a wealth of information concerning problems related to the Altithermal. Evidence of cultural occupation during this period is extremely rare. This period of desiccation marks the disappearance of Early Man assemblages and many kinds of fauna. Altithermal boundaries are not clear and may vary

from area to area but here again, further studies are desperately needed to resolve some of these problems.

c. The Middle Prehistoric Period

1) The McKean Site, 48 CK 7

On the basis of this excavation, many problems concerning Early Middle Period developments were explored. The only human skeletal remains known in the state from a definite Early Middle Period context were discovered here. Although valuable data was collected and reported, the site was inundated after completion of Keyhole Reservoir making further investigation impossible.

2) The Powers-Yonkee Bison Trap, 24 PR 5

This site is outside the study but was excavated by members of the Sheridan Chapter, Wyoming Archaeological Society, and relates directly to the area. This is an Early Middle Period Buffalo Kill. Many aspects of the site of interest to the professional investigator have never been studied.

3) The Powder River Site, 48 SH 312

This site is similar to site 24 PR 5. It is another record of an Early Middle Period Bison Kill in the study area.

4) The Mavrakis-Bentzen-Roberts Bison Trap, 48 SH 311

Aspects of this site are similar to 48 SH 312 and 24 PR 5, but is later in time. Material from the site has not been fully reported upon and will be further studied at the University of Wyoming.

5) The Ruby Site, 48 CA 302

This Late Middle Period site contains a more complete record of communal bison procurement activities than any other Middle Period site in the state. Along with the kill site was found a ceremonial structure and a camp area. The camp has not been fully investigated. The site was deeply buried and only recently exposed due to erosion.

6) The Glendo Reservoir Sites

Several Middle and Late Period campsites have been investigated in the area. Here, problematic stone-circles continue to mystify investigations. Evidence concerning what activities they represent has been elusive. Perhaps someday improved data collecting techniques will facilitate the investigator in extracting information from these sites.

7) The Lissolo Cave Site

This site contains both Early and Late Middle Period occupations but remains to be fully reported.

8) The Sweem-Taylor Site, 48 JO 301

Investigations here have not fully been reported. Occupations are Early and Late Middle Period with a hint of Late Early Period materials. The site yielded perishable materials which do not preserve in open sites.

9) The Lee Site, 48 NA 326

This is an Early Middle to Late Prehistoric site that has not been fully delineated or reported.

Sites from the Middle Prehistoric Period are more abundant than the Paleo Period. Many more known sites exist in the study area but remain to be evaluated. Several good sites are known to have been lost due to looters seeking to enrich their private collections. Many sites have been excavated and reported by conscientious amateurs. However, a professional interpretation of the wealth of material from this period is conspicuously lacking.

The era seems to be characterized by an increase in population, a diversity of cultural horizons, and perhaps some suggestion of the development of traditions based on adaptation of specific regions.

d. The Late Prehistoric Period

1) The Glenrock Buffalo Jump, 48 CO 404

The main contributions reported from this site were the developments of techniques for describing butchering processes and methods for aging buffalo which aided in determining seasonality of activities related to buffalo hunting.

2) The Vore Site

This site, a bison kill, contains the largest sample of bison bone known. The potential it offers for studies of Late Prehistoric bison populations is overwhelming.

3) The Piney Creek Sites, 48 JO 311 and 48 JO 312

The excavations documented Crow bison procurement activities represented by tool and ceramic assemblage from kill, camp and butchering areas.

4) The Big Goose Creek Site, 48 SH 313

This site is similar to the Piney Creek sites.

5) Medicine Creek Cave

This is a petroglyph and rockshelter site.

6) The PK Burials

Skeletal materials analyzed from this site added to what little is known about human morphological features of

Northwestern Plains people. However, the remains were examined out of context which unfortunately is the case for most skeletal remains from the area.

7) The Billy Creek Burials

The status of these remains is the same as the PK Burial.

8) The Foss Thomas Site

This is another Late Period buffalo kill that has not been fully investigated or reported.

9) The Kobold Site, 24 BH 406

Material from this site was excavated and reported by investigators from the University of Wyoming. Four components were found ranging from an Altithermal camp to Early Middle, Late Middle, and Late Prehistoric bison kills. Materials here have a direct bearing on the study area.

10) Spanish Diggings

The Spanish diggings is a very intensive stone quarry area covering several square miles. Investigations at the area have never been thorough but evidence suggests the quarries were used by people from all time periods.

The Late Prehistoric Period contains even more cultural material than the Middle Period. This is understandable since later materials are generally better preserved, but also reflects the acquisition of the horse in later times which led to a large increase in population. Also new to this time period is the bow and arrow and the development of ceramics.

In addition to the aforementioned sites exist literally hundreds of manifestations that have contributed less to the archaeological record. The full significance of most of these sites is not known due to lack of systematic investigation, professional interpretation, and reporting. Much of the work in the state has been left to well-meaning and earnest amateurs. This statement is not intended to slight the conscientious, talented, and enthusiastic amateur. Most of the major sites have been discovered by laymen and much of the work accomplished with their generously donated labor. The main problem lies in the lack of professional direction available to the amateur in his attempts to excavate sites and document data. Archaeological sites are repositories of scientific data and investigations of such phenomena ideally should be under the direction of a professional.

3. Conclusions and Recommendations

A search of the literature has substantially confirmed the abundance of archaeological resources in study area number one. George Frison, the person most familiar with the prehistory of the area, recently stated, "...a person can stand on the Wyoming-Colorado border and look from one buffalo jump, trap, or pound to another continuously to the forests of Canada." (Frison 1973:172). All time periods are represented along with numerous problems concerning prehistoric cultural developments. The area contains much potential for future problem-oriented investigations.

Studies in the area have progressed at a discouragingly slow rate. In referring to the same area twenty-five years ago Walter Wedel (Wedel 1949:330) wrote, "Unfortunately, despite very promising clues from surveys in the area, there has been relatively little systematic excavation on a scale commensurate with the problems involved." Several sites have been excavated since Wedel's observation, but still lacking is a well organized coordinating program to systematically inventory, study, and preserve archaeological resources. The most inhibiting factor has been the lack of funds for initiating and carrying out such a program.

Due to the energy crisis there is a critical need to begin developing energy resources in the study area. Industrial concerns are hurriedly compiling data to draft environmental assessments required of them before they can proceed with badly needed energy-related projects on public lands. Hopefully this rush will not force archaeologists to conduct inadequate investigations similar to those of the River Basin Survey era. A short-term, small-scale salvage program is not enough. A large-scale archaeological program is needed to meet immediate demands for a tremendous amount of work. Projects should be planned far enough in advance to allow time for thorough investigations without interfering with energy development schedules. Failure to initiate such a program will inevitably result in the loss of important archaeological materials.

Reports for study areas 2, 3 and 4 are in preparation and will be available soon.

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D. AN ARCHAEOLOGICAL SURVEY OF THE PROPOSED WYOMING COAL GAS COMPANY RESERVOIR AND TWO COAL GASIFICATION PLANT SITES IN NORTHEAST WYOMING

Prepared for
SERNCO, Incorporated
and
Wyoming Coal Gas Company

Submitted by Dr. David A. Breternitz
University of Colorado, Boulder

Prepared by Stephen J. Hallisy
University of Colorado, Boulder

July, 1974

At the request of SERNCO, Incorporated the University of Colorado conducted an archaeological survey of the proposed WCGC coal gasification complex in northeast Wyoming. The project was supervised by Mr. Stephen J. Hallisy of the University of Colorado. Hallisy, with the assistance of Mr. Howard K. Watts, walked over 2 potential plant sites and a reservoir complex during the period from June 24 through July 4, 1974. During the course of the survey, 8 prehistoric sites were encountered. Archaeological clearance is given for all but 2 of the 8 prehistoric site locations. Recommendations for the recovery of additional information at these 2 sites are suggested in order to mitigate the result of direct impact in the immediate vicinity.

1. Location of the Project Area

Two coal gasification plant sites (east and south sites) and a reservoir site comprise the study area of this report (figure C-3). The east plant site is located on the Campbell County line. The south plant site lies 16 miles northeast of Douglas, Wyoming on the east side of state highway 59. The proposed reservoir site is located north of the North Platte River in the Soldier Creek drainage area about 7 miles northeast of Douglas.

2. Environment

The physiography of the project area in the northeast portion of Wyoming is characterized as a rolling grass covered upland. The area lies within the Cheyenne River and the Upper Belle Fourche River drainages in the southeast portion of the Powder River basin in the unglaciated portion of the Missouri plateau section of the Great Plains physiographic province.

Elevation of the terrain in this region ranges from slightly more than 6,000 feet on Pine Ridge to 3,600 feet in the north part of Niobrara County. Relief is limited to a maximum of 500 feet and over most of the region it is less

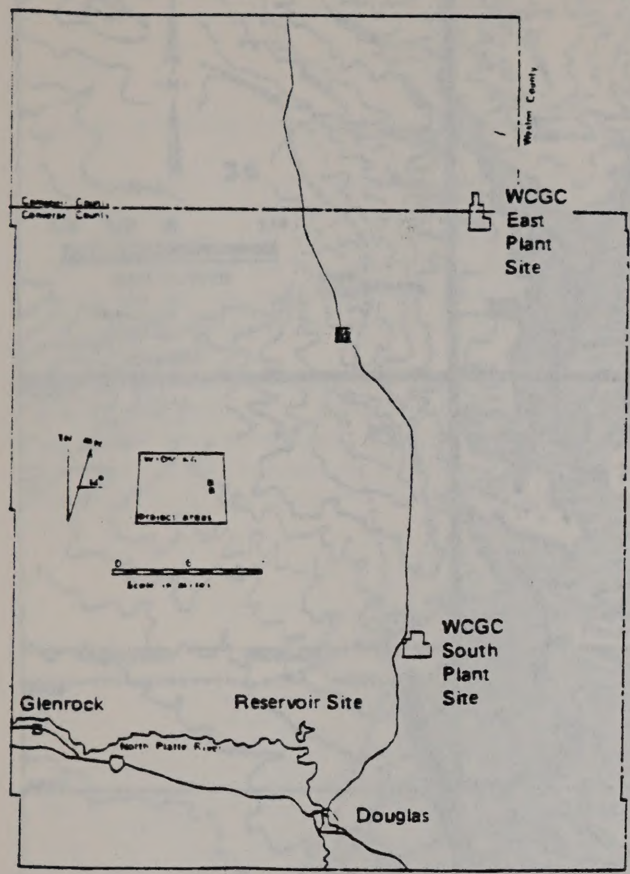

Figure C-3 Location of the east plant site, south plant site and proposed reservoir in Converse and Campbell Counties

than 250 feet. Surface materials include consolidated clay-shales, sandstones, and siltstones.

The climate in the region is semiarid. It is characterized by prevailing westerly winds and western mountain barriers which limit precipitation from 12 to 16 inches annually. Ephemeral streams in the foothills and plains are common because of their direct dependence on the low amount of annual precipitation. The absolute maximum/minimum range of temperatures is 106 F to −38 F, while the mean maximum/minimum range is 58 F to 33 F.

The biological environment of the project area is directly related to a precipitation gradient that increases in a northeast direction across the region. The proposed plant sites are situated in a transitional vegetation zone which contains many of the organisms found in either one or the other of 2 adjacent zones.

The native vegetation in this zone is represented by desert shrubs (mainly sagebrush) and short grasses. Sagebrush is replaced by greasewood and other shrubs in saline bottomlands or playas. Predominate grasses include blue grama and western wheatgrass.

A diversity of soil types have been recorded from samples taken in the east plant site area. Soils consisting of like amounts of clay, silt, and sand with variations in texture are classified as loams. Additional types include all clay texture or undifferentiated combinations of sandstone, shale, or limestone. Soils in the project area range from 24 to 36 inches in depth except in areas adjacent to ephemeral streams. Windblown deposits consist of fine tan yellow sand while loams are characteristically dark gray alluvial materials.

The fauna in the region include the following major classes: mammals, birds, invertebrates, amphibians, and reptiles. The mammal population includes mice, ground squirrels, Ord's kangaroo rats, rabbits and hares, coyotes, and big game characterized by elk, deer, and antelope. The value of these animals to the area as a food resource is often substantial.[1]

3. Methods

The survey was accomplished by a visual inspection of the proposed project area. In the field, a two man team walked over the areas involved and assessed the archaeological value of each site area located. For the purpose of this report, a prehistoric site is defined as "any place, large or small, where there are to be found traces of ancient occupation or activity" (Hole and Heizer 1969:59). Isolated finds of single artifacts were collected but were not considered sufficient evidence to justify designating the locality as a site.

All sites were located on U.S. Geological Survey 7.5' and 15' series maps. In the field, sites were tentatively numbered serially in the order in which they were found. Pertinent observations were recorded on University of Colorado survey forms and a representative surface collection of artifacts was taken at each site location. All surface collections, survey forms, original photographic negatives of each site, and a copy of the final project report will be made available to the office of the Wyoming State Archaeologist at Laramie.

Because an archaeological survey is necessarily limited to a surface inspection of potential cultural resources subsequent testing and excavation may be needed to determine the exact nature and extent of archaeological resources in a given region. Subsurface sites that leave no surface indications of previous cultural activities are often missed. Consequently, in the course of construction and earth moving activities in the project area additional evidence of archaeological resources may come to light. In this situation additional testing and excavation procedures are called for.

1 SERNCO, Inc. 1974. Second preliminary draft of applicant's environmental assessment of a proposed gasification project. SERNCO, Inc., Vol. 1, Denver Project Office.

A diversity of soil types have been recognized from samples taken in the east plant site area. Soils consisting of clay, silt, and sand with variations in texture are classified as loams. Additional types include all clay textures or unconsolidated clay containing lots of sandstone, shale, or limestone. Soils in the project area range from 2" to 30 inches in depth except in areas adjacent to intermittent streams. Windblown deposits consist of fine tan yellow sand which overlies predominantly dark gray alluvial materials.

The fauna in the region includes the following major classes: mammals, birds, invertebrates, amphibians, and reptiles. The mammal population includes black-tailed prairie dogs, Ord's kangaroo rat, rabbits and hares, coyotes, and big game characterized by elk, deer, and antelope. The value of these animals to the area is a food resource to inhabitants.[1]

2. METHODS

The survey was accomplished by a visual inspection of the proposed project area. In the field, a two man team walked over the areas involved and assessed the archaeological value of each site area located. For the purposes of this report, a prehistoric site is defined as "any place, large or small, where there are to be found traces of ancient occupation or activity" (Hole and Heizer 1969:59). Isolated finds of single artifacts were collected but were not considered sufficient evidence to justify designating the locality as a site.

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1 Stanford, Inc., 1974. Second preliminary draft of applicant's environmental assessment of a proposed gasification project, Inc., vol. 1, Denver Project Office.

Figure C-2. Location of the east plant site, south plant site and proposed reservoir in Converse and Campbell Counties.

than 250 feet. Surface materials include conglomerates, clay-shales, sandstones, and siltstones.

The climate of the region is semiarid. It is characterized by prevailing westerly winds and western mountain shadows which have precipitation from 12 to 16 inches annually. Ephemeral streams in the foothills and plains are common because of their total dependence on the low amount of annual precipitation. The absolute maximum-minimum range of temperatures is 106° F to −38° F, while the mean maximum-minimum range is 58° F to 33° F.

The biological environment of the project area is directly related to a precipitation gradient that increases in a northeast direction across the region. The proposed plant sites are situated in a transitional vegetation zone which contains many of the organisms found in either one or the other of 2 adjacent zones.

The native vegetation in this zone is represented by desert shrubs (mainly sagebrush) and short grasses. Sagebrush is replaced by greasewood and other shrubs in saline bottomlands or playas. Predominantly grasses include blue grama and western wheatgrass.

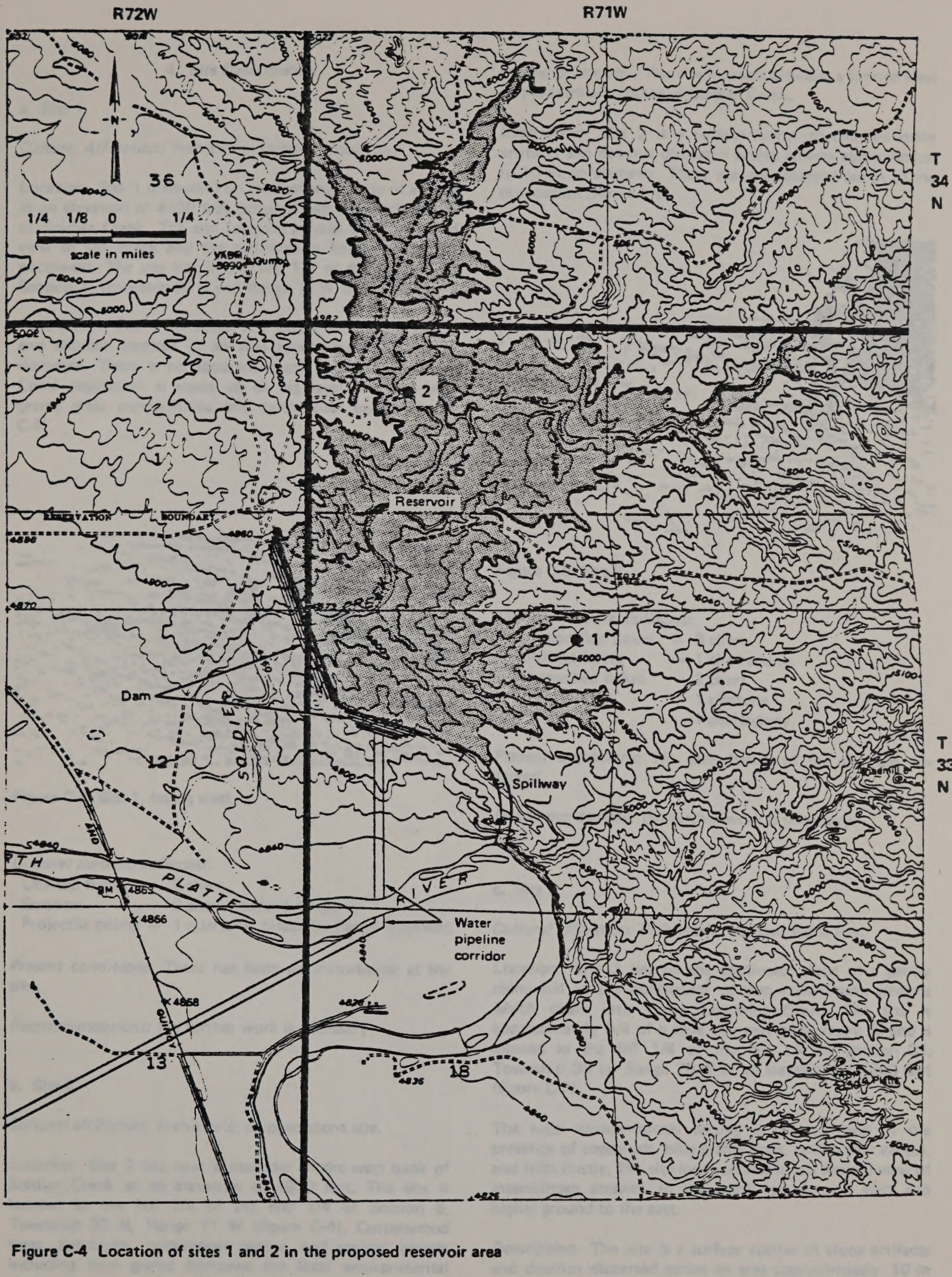

Figure C-4 Location of sites 1 and 2 in the proposed reservoir area

4. Site Descriptions

a. Site 1

Cultural Affiliation: Prehistoric; chipped stone site.

Location: Site 1 is situated on the east-west slope of a ridge at an elevation of 4920 feet between two minor tributaries of Soldier Creek. The site location affords an uninhibited view of the creek and the surrounding floodplain to the northwest. The site lies in the NE 1/4 of the NE 1/4 of Section 7, Township 33 N and Range 71 W (Figure C-4).

Description: Site 1 consisted of a scatter of stone artifacts and chipped detritus in an area approximately 50 m. in diameter. There is no apparent depth to the occupation. Local vegetation is made up of big sagebrush and blue grama grass communities and pricklypear cactus (figure C-5).

Figure C-5 Site 1, facing west

Cultural material collected:

Utilized flakes — 2 chert.
Scrapers — 2 chert side/end scrapers.
Projectile points — 1 quartzite, bifacially flaked fragment.

Present conditions: There has been no disturbance at the site.

Recommendations: No further work is necessary.

b. Site 2

Cultural affiliation: Prehistoric; chipped stone site.

Location: Site 2 lies near a meander of the west bank of Soldier Creek at an elevation of 4930 feet. The site is located in the NE 1/4 of the NW 1/4 of Section 6, Township 33 N, Range 71 W (figure C-4). Cottonwood trees, sagebrush, pricklypear cactus, and various grasses including blue grama comprise the local environmental setting of the site. The site location provides a limited view of the southern course of Soldier Creek.

Description: Site 2 is a surface scatter of chipped stone artifacts and detritus dispersed across an area approximately 10 m. in diameter. There was no apparent depth to the occupation (figure C-6).

Figure C-6 Site 2

Cultural material collected:

Unmodified flakes — 3 chert.
Utilized flakes — 1 chalcedony.
Retouched flakes — 2 chert
1 siltstone
1 chalcedony.

Present conditions: No disturbance of the site was observed.

Recommendations: No further work is necessary.

c. Site 3

Cultural affiliation: Prehistoric; chipped stone site.

Location: Site 3 lies on the southwest slope of a gently rising hill at the confluence of two intermittent streams which drain into Little Lightning Creek. The site is approximately 3/4 of a mile due east of highway 59 and is located in the NE 1/4 of the NE 1/4 of Section 33, Township 35 N, Range 70 W at an elevation of 5060 feet (figure C-7).

The local environmental setting is characterized by the presence of sagebrush, blue grama grass, pricklypear cactus, and Irish thistle. The site location provides a limited view of intermittent streams to the north, south, and west and higher ground to the east.

Description: The site is a surface scatter of stone artifacts and detritus dispersed across an area approximately 10 m

A. Site Descriptions

a. Site 1

Cultural affiliation: Prehistoric, chipped stone site.

Location: Site 1 is situated on the east-west slope of a ridge at an elevation of 4920 feet between two minor tributaries of Soldier Creek. The site location affords an unobstructed view of the creek and the surrounding topography to the northwest. The site lies in the NE 1/4 of the NE 1/4 of Section 1, Township 33 N and Range 71 W (Figure C-4).

Description: Site 1 consists of a scatter of chipped stone and chipped detritus in an area approximately 55 m in diameter. There is no apparent depth to the occupation. Local vegetation is composed of big sagebrush and blue grama grass communities, and pricklypear cactus (Figure C-5).

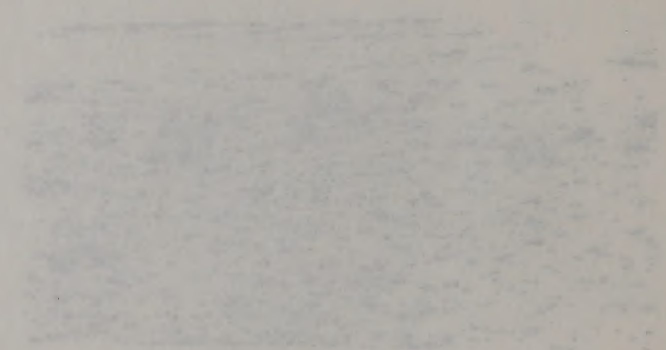

Figure C-5. Site 1, facing west.

Cultural materials collected:
- Utilized flakes — 2 chert.
- Debitage — 2 chert and 1 quartzite.
- Projectile points — 1 quartzite, probably a base fragment.

Present conditions: There has been no disturbance at the site.

Recommendations: No further work is necessary.

b. Site 2

Cultural affiliation: Prehistoric, chipped stone site.

Location: Site 2 lies near a meander of the west bank of Soldier Creek at an elevation of 4910 feet. The site is located in the NE 1/4 of the NW 1/4 of Section 6, Township 33 N, Range 71 W (Figure C-4). Cottonwood trees, sagebrush, pricklypear cactus, and various grasses including blue grama comprise the local environmental setting of the site. The site location provides a sheltered view of the southern margin of Soldier Creek.

Description: Site 2 is a surface scatter of chipped stone artifacts and debitage dispersed across an area approximately 10 m in diameter. There was no apparent depth to the occupation (Figure C-6).

Figure C-6. Site 2.

Cultural materials collected:
- Unmodified flakes — 2 chert.
- Utilized flakes — 1 chalcedony.
- Retouched flakes — 2 chert.
  - 1 quartzite.
  - 1 chalcedony.

Present conditions: No disturbance of the site was apparent.

Recommendations: No further work is necessary.

c. Site 3

Cultural affiliation: Prehistoric, chipped stone site.

Location: Site 3 lies on the southwest slope of a gently rising hill at the confluence of two intermittent streams which drain into Little Lightning Creek. The site is approximately 3/4 of a mile due east of Highway 59 and is located in the SE 1/4 of the NE 1/4 of Section 27, Township 36 N, Range 70 W at an elevation of 5060 feet (Figure C-7).

The local environmental setting is characterized by the presence of sagebrush, blue grama grass, pricklypear cactus, and brush. The site location provides a limited view of intermittent streams to the north, south, and west and higher ground to the east.

Description: The site is a surface scatter of stone artifacts and debitage dispersed across an area approximately 70 m

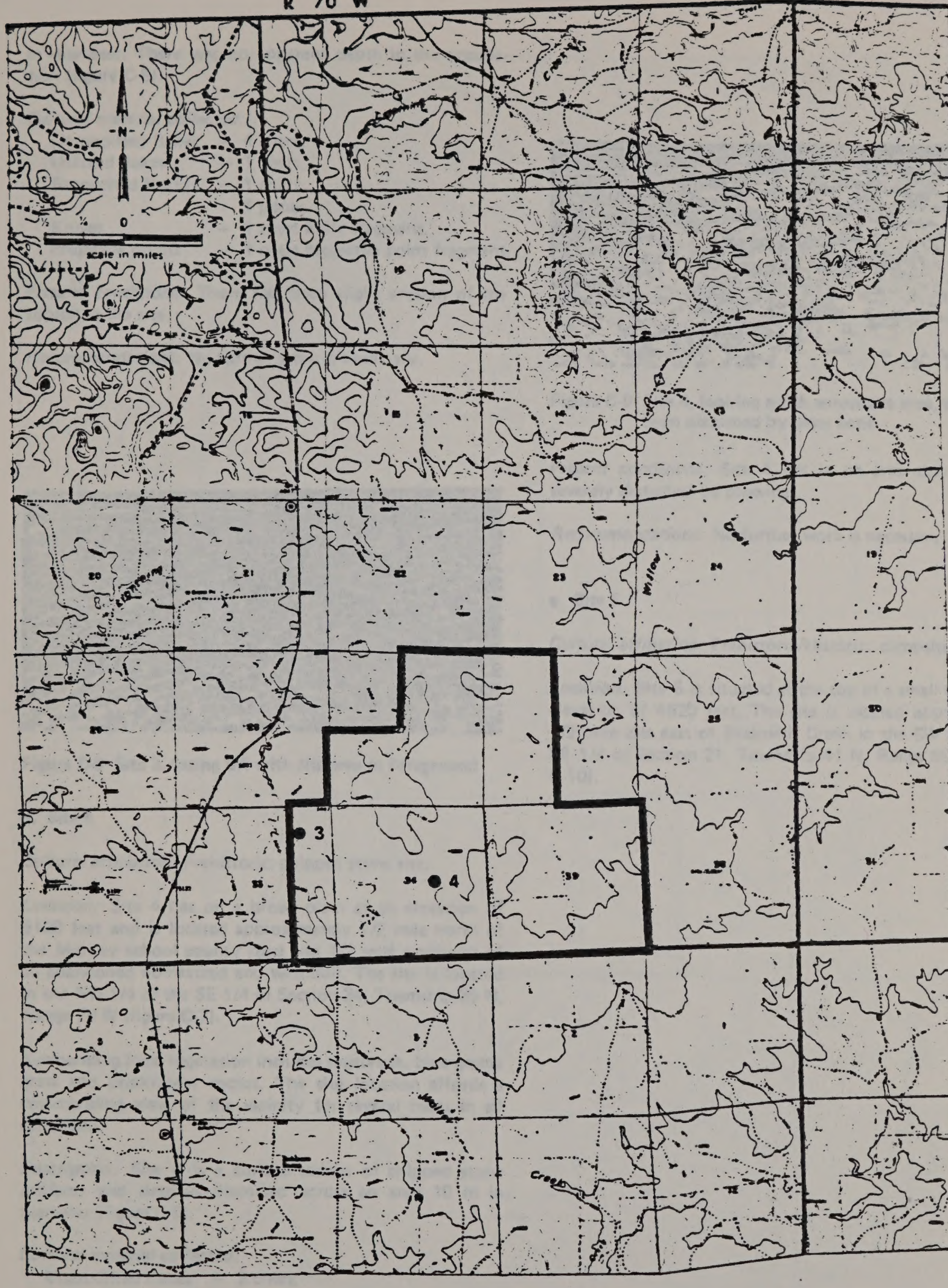

Figure C-7 Location of sites 3 and 4 on the south plant

in diameter. There was no apparent depth to the occupation (figure C-8).

Cultural material collected:

Unmodified flakes	— 4 chert.
Utilized flakes	— 1 chert.
Retouched flakes	— 1 chert
	1 jaspar.
Knives	— 1 chert knife fragment.
Projectile points	— 1 chert projectile point fragment.

Present conditions: There has been slight erosion of the topsoil at the site.

Recommendations: No further work is necessary.

Figure C-8 Site 3, facing SW with site area in foreground

d. Site 4

Cultural affiliation: Prehistoric; chipped stone site.

Location: Site 4 lies on a broad plain at an elevation of 5100 feet and is located approximately 1/2 mile north of the Midway school county road and 1/2 mile northeast of an abandoned homestead and windmill. The site is located in the NW 1/4 of the SE 1/4 of Section 34, Township 35 N, Range 70 W (figure C-7).

Surrounding local vegetation includes sagebrush, blue grama grass and pricklypear cactus. The site location affords a commanding view of the vicinity for several miles in all directions.

Description: Site 4 is a surface scatter of chipped stone artifacts and detritus dispersed across an area 10 m in diameter (figure C-9).

Cultural material collected:

Unmodified flakes	— 2 chert.
Retouched flakes	— 2 chert.
Cores	— 1 chert bifacially flaked cores.
Projectile points	— 1 jasper triangular side notched projectile point.

Figure C-9 Site 4, looking north across site area, which has been disturbed by plow zone

Present conditions: Site 4 lies in an area that has been severely disturbed by plowing.

Recommendations: No further work is necessary.

e. Site 5

Cultural affiliation: Prehistoric/Historic; campsite.

Location: Site 5 is situated at the top of a small knoll at an elevation of 4620 feet. The site is located approximately 1/2 mile due east of Beckwith Creek in the SW 1/4 of the SE 1/4 of Section 21, Township 41 N, Range 69 W (figure C-10).

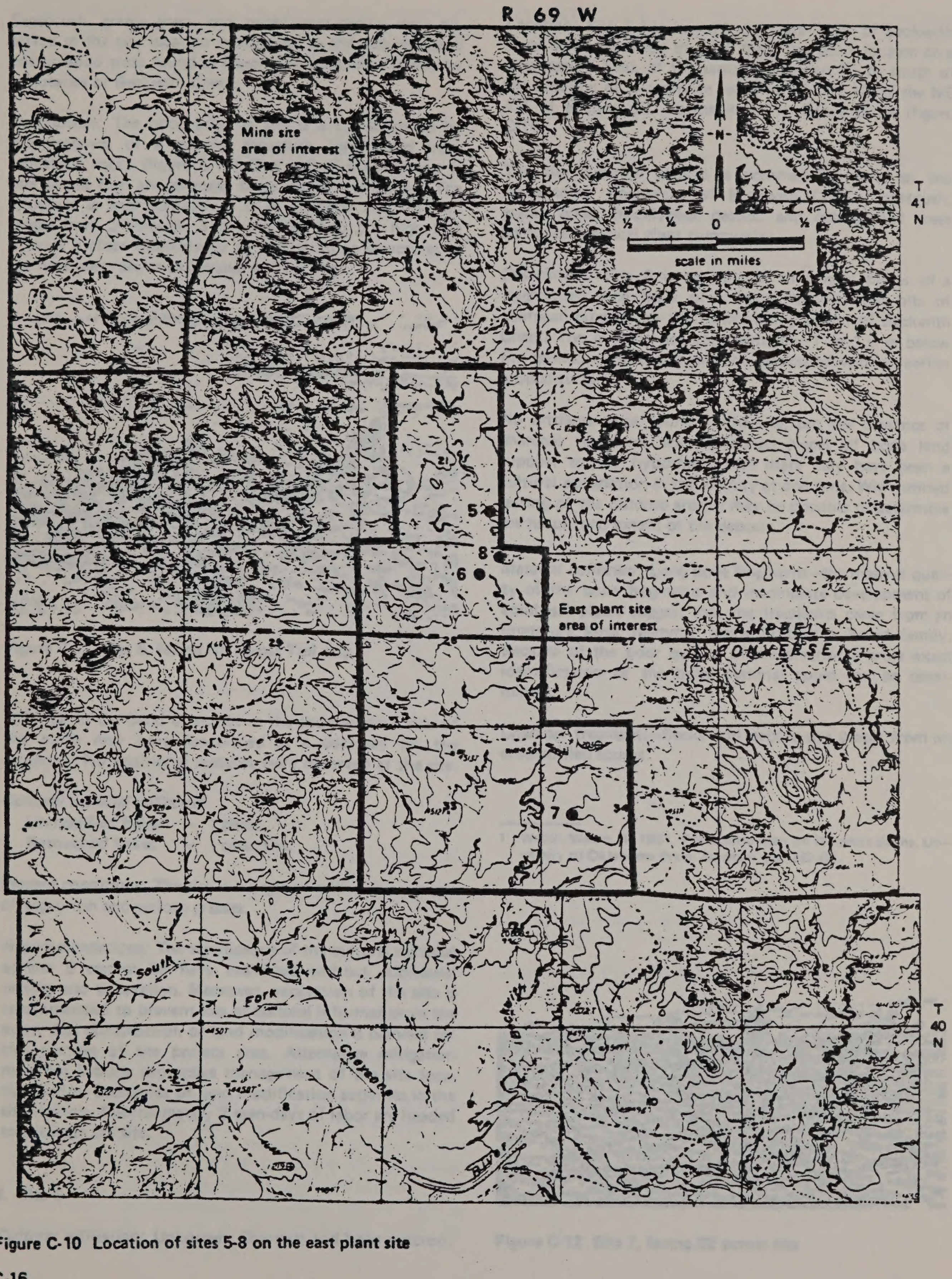

Figure C-10 Location of sites 5-8 on the east plant site

Sagebrush, grama grass, and pricklypear cactus were observed at the site location in addition to the occurrence of cottonwood trees found at lower elevations close to nearby tributaries of Beckwith Creek.

Description: The occupation at site 5 is characterized by the presence of a circular structure constructed from sandstone rocks (figure C-11). The wall of the structure is one course high and averages three stones in thickness. The structure is approximately 3 m in diameter and the wall ranges from .2 through .3 m wide and .1 to .3 m high. Site 5 bears a close resemblance to similar stone structures in the northwest plains designated as Tipi rings.[1]

Figure C-11 Site 5, facing NE across Tipi ring

A break in the band of stones in the southwestern side of the circle may have functioned as a doorway for the structure. No additional features were observed at the site.

Cultural material collected:

Unmodified flakes — 1 chert.
Retouched flakes — 1 quartzite.

Present conditions: The site is overgrown with a dense cover of sagebrush and various grasses.

Recommendations: The significance of the cultural material at site 5 cannot be fully evaluated without additional testing and excavation. Moreover, excavation of the site is recommended to prevent loss of cultural information in the event that construction or land modification is planned for this portion of the project area. Alternative mitigation measures include protective management of the site location and/or avoidance of land modification activities in the site vicinity. Approximately 2 man-days of labor are needed to excavate the site.

f. Site 6

Cultural affiliation: Unknown; Charcoal and bone outcrop.

Location: Site 6 lies beneath the south bank of Beckwith Creek at an elevation of 4560 feet. The site is located on a meandering bank of the streambed about 75 m south of the junction of two service roads in the NW 1/4 of the NE 1/4 of Section 28, Township 41 N, Range 69 W (figure C-10).

The site location affords a commanding view of the surrounding floodplain of Beckwith Creek. Sagebrush, grama grass, pricklypear cactus, and cottonwood trees comprise the local plant community.

Description: Site 6 is an outcrop of several pieces of a fragmented long bone of a large mammal and bits of charcoal exposed by the downcutting action of Beckwith Creek. The outcrop lies approximately 1 to 1.5 m below the ground surface and may be associated with an earlier ground surface.

No artifacts were found at the site, but the presence of charcoal fragments and associated pieces of bone lend support to the hypothesis that there may have been a cultural occupation in the vicinity at one time. With limited testing of the outcrop area, it may be possible to determine the nature and extent of the deposit.

Material collected: Long bone fragments—the massive quality of the bone fragments and incomplete development of epiphesal plates suggest that the fragments came from an immature large mammal probably of the Bovid family. Because of the poor quality of preservation a more exact identification of the bony material could not be determined.

Charcoal fragments—flecks and pebble size pieces from an unidentified source.

1 Wedel, Waldo R. 1961. Prehistoric man on the great plains. University of Oklahoma Press: Norman, pp. 262-66.

Figure C-12 Site 7, facing SE across site

Present conditions: Because the site is located beneath the south bank of an intermittent stream bed an unknown portion of the deposit has been destroyed by previous erosion of the watercourse.

Recommendations: It is strongly suggested that steps be taken to mitigate unavoidable adverse effects leading to the destruction of potential cultural resources at the site. In order to determine the nature and extent of the site deposit, it is suggested that exploratory excavation and testing be undertaken. This precaution will insure that a more complete knowledge of potential cultural materials is secured prior to potential alternation of the landscape in the site vicinity. Approximately 4 man-days would be required to excavate the site.

g. Site 7

Cultural affiliation: Prehistoric; chipped stone site.

Location: Site 7 lies on a gently sloping rise at an elevation of 4520 feet. The site is located approximately 350 m east of Beckwith Creek and 1/4 mile south of a stock pond and adjacent service road in the NW 1/4 of the SW 1/4 of Section 34, Township 41 N, Range 69 W (figure C-10).

The site location provides an uninhibited view of lower elevations of the north, south, and west of the site. The local environment setting is characterized by yucca, sagebrush, grama grass, pricklypear cactus, and cottonwood trees.

Description: Site 7 is a surface scatter of chipped stone artifacts and detritus spread across an area 25 m in diameter (figures C-12).

Cultural material collected:

Unmodified flakes — 3 quartzite
6 chert.
Retouched flakes — 1 chert.
Scrapers — 1 bifacially flaked end/side scraper.

Present conditions: The site location has undergone slight erosion.

Recommendations: No further work is necessary.

h. Site 8

Cultural affiliation: Prehistoric/Historic; campsite.

Location: The site is located atop a small knoll approximately 1/4 mile southeast of site 5 and 200 m west of a windmill in the NE 1/4 of the NE 1/4 of Section 28, Township 41 N, Range 69 W (figures C-10). Sagebrush, grama grass, pricklypear cactus and cottonwood trees comprise the local vegetation surrounding the site. The site situation affords a view of the surrounding terrain for several miles in all directions.

Description: Site 8 is characterized by 2 archaeological features; a stone lined fireplace and associated stone cairn. The fireplace is approximately two courses high and 1 m in diameter. A stone cairn about 1 m in diameter is situated about 1 m to the south of the fireplace. No artifacts were found at the site (figure C-13).

Present conditions: There has been slight erosion of the surface in the site vicinity.

Recommendations: No further work is necessary.

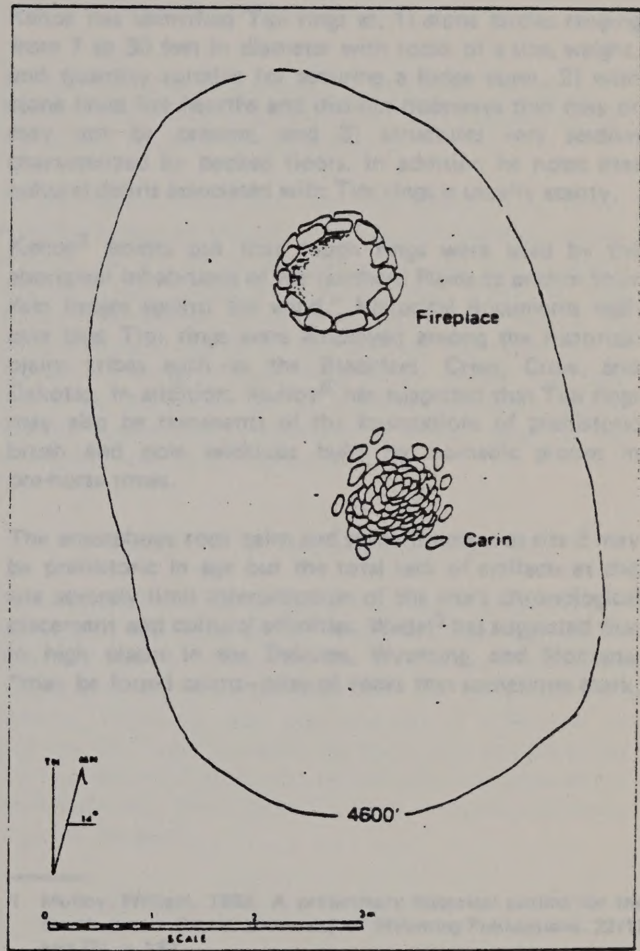

Figure C-13 Plan of site 8 in northeast Wyoming

Isolated finds: The following group of artifacts constitutes a collection of isolated artifacts found within the study area. A single object was not considered sufficient evidence to justify designating a locality as a site.

Unmodified flakes	–	5 chert 1 chalcedony.
Utilized flakes	–	1 chert.
Retouched flakes	–	1 chert 1 chalcedony.
Knives	–	1 chert fragment, bifacially flaked with edges retouched.
Projectile points	–	1 quartzite projectile point fragment 1 chert projectile point fragment 1 iron (scrap metal) projectile point.

Two fragmentary stone projectile points were recovered from the reservoir site area in Section 7, Township 33 N, Range 71 W. They show a general affinity to lanceolate shaped projectile points characteristic of the Early Middle Prehistoric period (2500 B.C.) of the northwest Plains area.[1]

A single iron, lanceolate shaped projectile point was recovered about 1/4 mile south of site 3 on a gently sloping rise in the SE 1/4 of the NE 1/4 of Section 33, Township 70 W, Range 35 N. The point is representative of European contact. It is indicative of factory produced points that were traded to the Nebraska Sioux. The Sioux used this type of projectile point to tip war arrows used in raids against trappers. Representative specimens can be viewed in the Custer Battlefield Museum.[2]

5. Discussion

Evidence of prehistoric occupation in the proposed WCGC reservoir and coal gasification plant site areas is rare. A pedestrian survey of the project area produced a total of 8 archaeological sites. At least 3 distinct types of sites were encountered. The inventory includes 5 chipped stone sites (nos. 1, 2, 3, 4, & 7), 2 camp sites (nos. 5 & 8), and one subsurface outcrop of a potential prehistoric occupation (no. 6).

Chipped stone sites were characterized by a surface scatter of lithic artifacts and detritus. Artifacts include modified and unmodified flakes, knives, scrapers, and projectile points. No features were observed at any of the sites recorded. The sites probably represent stone knaping activities of past aboriginal hunting and gathering groups.

Because of the general nature of the artifact collections it is impossible to assign any of the chipped stone sites to a definite period or known archaeological culture. Similar archaeological assemblages of chipped stone tools have been recognized as the material cultural remains of prehistoric hunting and gathering groups of the northwest Plains.[3] A single side notched projectile point recovered from site 4 displays a general affinity to projectile point styles repre-resentative of the Middle Prehistoric period dated at 2500 B.C. to A.D. 500.[4]

Sites 5 and 8 are aboriginal camp sites but the lack of diagnostic artifacts does not allow assignment of a representative time period or culture complex. A circular stone structure at site 5 bears close resemblance to similar prehistoric/historic sites in the Wyoming/Montana area designated as Tipi rings.[3,5,6]

Kehoe has identified Tipi rings as, 1) stone circles ranging from 7 to 30 feet in diameter with rocks of a size, weight, and quantity suitable for securing a lodge cover, 2) with stone lined fire hearths and distinct doorways that may or may not be present, and 3) structures very seldom characterized by packed floors. In addition he notes that cultural debris associated with Tipi rings is usually scanty.

Kehoe[5] points out that "such rings were used by the aboriginal inhabitants of the northern Plains to anchor their skin lodges against the wind." Historical documents indicate that Tipi rings were employed among the historical plains tribes such as the Blackfeet, Crees, Crow, and Dakotas. In addition, Mulloy[6] has suggested that Tipi rings may also be remanents of the foundations of prehistoric brush and pole wickiups built by nomadic groups in pre-horse times.

The amorphous rock cairn and stone fireplace at site 8 may be prehistoric in age but the total lack of artifacts at this site severely limit interpretation of the site's chronological placement and cultural affinities. Wedel[3] has suggested that in high places in the Dakotas, Wyoming, and Montana, "may be found cairns—piles of rocks that sometimes mark,

1 Mulloy, William. 1958. A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications. 22(1) and (2). p. 161.

2 Russell, Carl P. 1967. Firearms, traps, and tools of the mountain men. Alfred A. Knopf. New York. p. 319, 329-29 figure 84s, p. 321.

3 Wedel, Waldo R. 1961. Prehistoric man on the great plains. University of Oklahoma Press: Norman.

4 Mulloy, William. 1958. A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications. 22(1) and (2). p. 162.

5 Kehoe, Thomas F. 1958. Tipi Rings—the direct 'ethnological approach' applied to an archaeological problem. American Anthropologist 60(5):861-73.

6 1965. Archaeological investigations along the north Platte River in eastern Wyoming. University of Wyoming Publications. 31(2): 23-50.

or are locally thought to mark, Indian graves, boundary lines, or other features, but which seem more often to have been erected for reasons that still elude us."

The nature of potential archaeological resources at site 6 can only be determined by additional testing and excavation of the site. A 1 foot square outcrop of charcoal fragments and pieces of a fragmented mammal long bone were exposed in a dark gray layer of alluvium approximately 1 to 1.5 m below the present ground surface. The complete absence of artifactual materials at the site restricts the necessary evidence one needs for judging whether or not 1) the association of bone and charcoal fragments in the deposit is adequately explained as the result of natural geological processes or 2) the remains of prehistoric cultural activities in the site vicinity. Exploratory excavation of the site is necessary to answer these questions.

At this time it is not possible to provide a range of dates for prehistoric occupation in the project area. However, artifacts collected from the chipped stone sites indicate that prehistoric man may have occupied the area as early as 2500 B.C. during the Middle Prehistoric period of the Northwest Plains region.[1]

6. Guidelines for the Mitigation of Adverse Effects on Archaeological Resources

The primary purpose of an archaeological survey is to secure "a comprehensive and extended physical examination of an area, for the purpose of obtaining an accurate sample of data on all archaeological resources, situations, and associated environmental variables."[2] Information obtained from a field reconnaissance of potentially affected resources is acquired to 1) predict the effect of the action on the resource, and 2) recommend a program for mitigating adverse effects on the resources.

Adverse effects result from any direct or indirect impact on archaeological resources. Direct impacts involve destruction of archaeological resources and their environment through earth-moving, plowing, flooding, or building construction. Indirect impacts are a product of an action which would expose resources, either within or adjacent to the development, to indirect disturbance such as commercial building, increased vandalism, or road building.

Alternatives to proposed action which may adversely affect archaeological resources should be evaluated primarily on the basis of the "extent to which they permit preservation of resources and their context for future study and enjoyment."[2] Specific alternative actions include preservation of sites through protective management measures and mitigation measures using scientific studies.

In the event that WCGC project actions will potentially cause adverse effects at site locations 5 and 6, it is strongly recommended that the proposed program guidelines for the mitigation of adverse affects on archaeological resources be strictly adhered to. Archaeological clearance is given for the remainder of the project area.

It was not possible to obtain Smithsonian Institution River Basin Survey site designations from the Wyoming State Archaeologist prior to publication of this report. Hence, sites reported on in this study retain their tentative field designations. The following county names are listed for each site so that proper site designations can be used at a future date.

Sites 1, 2, 3, 4, and 7—Converse County.
Sites 5, 6, and 8—Campbell County.

E. AN ARCHAEOLOGICAL SURVEY OF A PROPOSED COAL GASIFICATION PLANT SITE IN NORTHEAST WYOMING

At the request of SERNCO, Inc., the author, H. K. Watts, with the assistance of Cathy J. Watts, conducted an archaeological survey of a proposed coal gasification plant site (the north plant site) in northeast Wyoming. This survey was conducted during the period from August 19 through August 22, 1974, and involved the inspection of 2.5 square miles of land. This survey yielded only one prehistoric site which was of dubious significance. Consequently, archaeological clearance is hereby given for the entire area covered by this survey.

1. Location of the Proposed North Plant Site

The extent of this survey was limited to one proposed coal gasification plant site located in the southeast portion of Campbell County, Wyoming. The proposed site comprises 1600 acres and lies approximately 51 miles south of Gillette, Wyoming, and approximately 3 miles east of highway 59. Topographically the north plant site comprises the high ground between the two principal drainages of the immediate area, Black Butte Creek to the north and Horse Creek to the south.

2. Survey Method

The survey of the north plant site was accomplished by a visual inspection of the area. In the field, a two man party walked the project area in a systematic pattern. In addition, areas of suspect archaeological significance were subjected to intense inspection.

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1 Mulloy, William. 1958. A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications. 22(1) and (2).

2 Scoville, Douglas H., Garlan J. Gordon, and Keith M. Anderson. 1972. Guidelines for the preparation of statements of environmental impact or archaeological resources. Arizona Archaeological Center. National Park Service, Tucson, Arizona.

strictly adhered to. Archaeological clearance is given for the remainder of the project area.

It was not possible to obtain Smithsonian Institution River Basin Survey site designations from the Wyoming State Archaeologist prior to publication of this report; hence, sites reported on in this study retain their temporary field designations. The following county names are listed for each site so that proper site designations can be used at a future date.

Sites 1, 2, 3, 4, and 7—Converse County
Sites 5, 6, and 8—Campbell County

E. AN ARCHAEOLOGICAL SURVEY OF A PROPOSED COAL GASIFICATION PLANT SITE IN NORTHEAST WYOMING

At the request of BERNCO, Inc., the author, H. K. Wells, with the assistance of Larry L. Smith, conducted an archaeological survey of a proposed coal gasification plant site (the north plant site) in northeast Wyoming. The survey was conducted during the period from August 19 through August 22, 1974, and involved the inspection of 2.5 square miles of land. This survey yielded only one prehistoric site which was of marginal significance. Consequently, archaeological clearance is hereby given for the entire area covered by this survey.

1. Location of the Proposed North Plant Site

The scope of this survey was limited to the proposed coal gasification plant site located in the southeast portion of Campbell County, Wyoming. The proposed site comprises 1600 acres and lies approximately 51 miles south of Gillette, Wyoming, and approximately 3 miles east of highway 59. Topographically the north plant site comprises the high ground between the two principal drainages of the immediate area, Black Thunder Creek to the north and Hay Creek to the south.

2. Survey Methods

The survey of the north plant site was accomplished by a visual inspection of the area. In the field a two man party walked the project area in a systematic pattern. In addition, areas of suspect archaeological significance were subjected to intense inspection.

1. Mulloy, William. 1958. A preliminary historical outline for the Northwestern Plains. University of Wyoming Publications. 22(1) and (2).

2. Scovill, Douglas H., Garland J. Gordon, and Keith M. Anderson. 1972. Guidelines for the preparation of statements of environmental impact on archeological resources. Arizona Archeological Center, National Park Service, Tucson, Arizona.

or are locally enough to mark, Indian graves, boundary lines, or other features, but which seem more often to have been erected for reasons that still elude us.

The nature of buried archaeological resources at site 9 can only be determined by additional testing and excavation of the site. A 1 foot square cutout of charcoal fragments and pieces of a fragmented mammal long bone were exposed in a dark gray layer stratigraphically approximately 1 to 1.5 m below the present ground surface. The consistent absence of artifactual material at the site raises the possibility [illegible] and 1) the association of bone and charcoal [illegible] in the deposit is adequately explained as the result of natural geological processes or 2) the remains of prehistoric cultural activities in the site vicinity. Stratigraphic excavation of the site is necessary to answer these questions.

At this time it is not possible to propose a range of dates for prehistoric occupation of the project area. However, artifacts collected from the adjacent stone sites indicate that prehistoric man may have occupied the area as early as 2500 B.C. during the Middle Prehistoric period of the Northwestern Plains region.[1]

6. Guidelines for the Mitigation of Adverse Effects on Archaeological Resources

The primary purpose of an archaeological survey is to obtain "a comprehensive and extended physical examination of an area, for the purpose of obtaining an accurate record of each or all archaeological resources, situations, and associated environmental variables."[2] Information obtained from a field reconnaissance of potentially affected resources is required to 1) predict the effect of the action on the resource, and 2) recommend a program for mitigating adverse effects on the resources.

Adverse effects result from any direct or indirect impact on archaeological resources. Direct impacts involve destruction of archaeological resources and their environment through earth-moving, plowing, flooding, or building construction. Indirect impacts are a product of an action which would expose resources, either without requirement to the development, to indirect disturbance such as commercial building, increased vandalism, or road building.

Alternatives to proposed action which may adversely affect archaeological resources should be evaluated primarily on the basis of the "extent to which they permit conservation of resources and their context for future study and enjoyment."[2] Specific alternative actions include preservation of sites through protective management measures and mitigation measures using specific studies.

In the event that WGCC project actions will potentially cause adverse effects at site locations 9 and 10, it is strongly recommended that the proposed project guidelines for the mitigation of adverse effects on archaeological resources be

As previously stated, only one prehistoric site was discovered in the study area. In various localities throughout the study area isolated artifacts representing prehistoric utilization of the land to a limited degree were found; however, these finds were not considered sufficient evidence to call the locale a site.

The one prehistoric site that was discovered was indicated on a (1971) U.S.G.S. Teckla SW Quadrangle, Wyoming-Campbell Co., 7.5 minute series map. Pertinent information regarding this site was recorded on a University of Colorado archaeological survey form. The map indicating the site location, a copy of the survey form, artifacts collected, and a copy of this report have been sent to the Wyoming State Archaeologist, Laramie.

Finally, it should be noted that any sub-surface evidence of prehistoric human occupation that may come to light during construction activities in this study area will require further inspection and possible excavation.

3. Description of Site 1

a. Site 1

Cultural Affiliation: Unknown

Location: Site 1 is located at an elevation of 4980 ft. above sea level approximately 2 miles south of Black Butte Creek. This is the highest point in the general vicinity and provides an unobstructed view of the gently sloping land that forms the immediate drainage to Black Butte Creek to the north and Horse Creek to the south. Specifically the site lies in the NE¼ of the NE¼ of Section 5, Township 41N and Range 71W.

Description: Site 1 consisted of a lithic concentration of chipped stone artifacts and flakes in an area approximately 25 yards in diameter. There is no apparent depth to the site. Present vegetation consists of communities of sagebrush, pricklypear cactus, and coarse grasses. The land is presently utilized for the grazing of sheep and cattle.

Cultural Material Collected:

Utilized Flakes:	1 chert
	1 quartzite
	1 coarse grain volcanic
Waste Flakes:	2 chert
Projectile Points:	1 chert, crude and bifacially flaked
Cores:	1 chert

Discussion: Site 1 appears to represent a fairly recent utilization of the land, consisting only of a limited amount of materials scattered on the surface. The site appears to have been utilized as a chipping station while watching for game animals to enter the lower elevations to graze and water.

Recommendations: No further work is necessary.

4. Isolated Artifacts

The following list of prehistoric stone artifacts were discovered as isolated specimens within the study area, but did not provide sufficient evidence to call locales sites:

Waste Flakes:	2 quartzite
	2 chert
Utilized Flakes:	1 chert
	1 quartzite
Projectile Points:	1 chert, bifacially flaked fragment
Knives:	1 chert, bifacially flaked fragment

5. Summary and Conclusion

Surface evidence of prehistoric human occupation and utilization of the land within this study area is indeed scanty. The only site discovered appears to represent a chipping station where prehistoric occupants of this area made stone hunting tools while watching for game animals to enter the area. From the limited amount of artifacts and waste materials found it is apparent that this site had relatively little use in this respect.

Isolated surface finds were also scanty and indicate a relatively limited utilization of this area prehistorically. The total lack of surface evidence to denote campsites is noteworthy.

In conclusion, archaeological clearance is given for the entire north plant site area although it will be necessary to keep in mind the possibility that sub-surface sites of archaeological significance might exist in this area. These, of course, may come to light during construction activities and will necessitate further inspection and possible excavation.

APPENDIX 4-C. PLANT SITE STUDIES, SOCIO-ECONOMICS

A. INTRODUCTION

This appendix is a compilation of supplemental socio-economic data, in graphic and tabular form, pertinent to a better understanding of the economic, land use and housing characteristics of the project area.

B. ECONOMIC DATA

1. Total Earnings by Source, Tables D-1 through D-7

The following seven tables D-1 through D-7, contain data taken from 1973 *Obers Projections*[1] and unpublished data from the Bureau of Economic Analysis[2] (BEA) for Converse and Campbell Counties. The tables contain data on total earnings by source for nine major industry groups for selected years 1950, 1959, 1962, 1968, and 1969 for Wyoming and the U.S. as well as 1950, 1959, 1962, 1968, 1970, and 1971 for Campbell and Converse Counties.

Earnings by source is defined as the sum of income accruing to persons from wage and salary disbursements, proprietor's income and labor income.

Tables D-1 through D-5 are in constant dollars (standard base year 1967), where the Campbell and Converse Counties data tables D-6 and D-7, is in current dollars. The "percent of total" figures were calculated by SERNCO for comparisons of Wyoming to the U.S. historical earnings by source.

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1 Obers Projections, prepared by the U.S. Department of Commerce, Social and Economics Statistics Administration, Bureau of Economic Analysis, Regional Economics Division and the U.S. Department of Agriculture, Economics Research Service, Natural Research Economics Division for the U.S. Water Resource Council. September 1972. Five volumes.

2 Special unpublished report. Regional economics information system, bureau of economic analysis. U.S. Department of Commerce, Social and Economic Statistics Administration. August, 1973.

Table D-1. 1950 Total earnings by source, Wyoming vs. the U.S. (thousand 1967 dollars)

	1950[a]		% of Total	
Source	Wyoming	United States	Wyoming	U.S.
Total earnings	$558,595	$258,747,759	100.0	100.0
Agriculture, forestry, fisheries	109,161	23,597,264	19.5	9.1
Mining	53,799	5,145,232	9.6	2.0
Contract construction	45,540	15,483,087	8.1	6.0
Manufacturing	34,034	74,817,598	6.1	28.9
Transportation, communications, public utilities	74,021	21,131,028	12.9	8.1
Wholesale & retail trade	99,680	48,939,614	17.8	18.9
Finance, insurance, real estate	14,585	10,911,234	2.6	4.2
Services	41,142	28,904,344	7.4	11.2
Government	88,741	29,818,358	15.9	11.5

(a) Data from 1972 OBERS projections.

Table D-2. 1959 Total earnings by source, Wyoming vs. the U.S. (thousand 1967 dollars)

Source	1959[a] Wyoming	1959[a] United States	% of Total Wyoming	% of Total U.S.
Total earnings	$670,169	$355,766,604	100.0	100.0
Agriculture, forestry, fisheries	91,882	17,042,358	13.7	4.8
Mining	73,225	5,149,264	10.9	1.4
Contract construction	74,423	21,852,640	11.2	6.1
Manufacturing	50,542	107,255,073	7.5	30.1
Transportation, communications, public utilities	75,982	27,392,039	11.3	7.7
Wholesale & retail trade	108,012	63,499,623	16.2	17.8
Finance, insurance, real estate	20,311	18,109,611	3.0	5.1
Services	68,338	45,244,956	10.2	12.7
Government	107,465	50,221,040	16.0	14.1

(a) Data from 1972 OBERS projections.

Table D-3. 1962 Total earnings by source, Wyoming vs. the U.S. (thousand 1967 dollars)

Source	1962[a] Wyoming	1962[a] United States	% of Total Wyoming	% of Total U.S.
Total earnings	$691,270	$389,998,433	100.0	100.0
Agriculture, forestry, fisheries	78,084	18,462,090	11.3	4.7
Mining	69,812	4,908,611	10.1	1.3
Contract construction	69,982	22,990,095	10.1	5.9
Manufacturing	50,374	115,576,458	7.3	29.6
Transportation, communications, public utilities	79,652	28,694,815	11.5	7.4
Wholesale & retail trade	112,496	67,565,645	16.3	17.3
Finance, insurance, real estate	21,816	19,805,660	3.2	5.1
Services	77,560	52,608,614	11.2	13.5
Government	131,493	59,386,445	19.0	15.2

(a) Data from 1972 OBERS projections.

Table D-4. 1968 Total earnings by source, Wyoming vs. the U.S. (thousand 1967 dollars)

Source	1968[a] Wyoming	1968[a] United States	% of Total Wyoming	% of Total U.S.
Total earnings	$774,704	$529,659,952	100.0	100.0
Agriculture, forestry, fisheries	74,001	18,415,005	9.5	3.5
Mining	89,323	5,274,946	11.5	1.0
Contract construction	63,852	31,676,705	8.2	6.0
Manufacturing	52,373	155,607,034	6.8	29.4
Transportation, communications, public utilities	79,226	36,552,940	10.2	6.9
Wholesale & retail trade	114,300	87,077,150	14.8	16.4
Finance, insurance, real estate	27,573	27,739,804	3.6	5.2
Services	93,806	77,245,516	12.1	14.6
Government	180,251	90,070,855	23.3	17.0

(a) Data from 1972 OBERS projections.

Table D-5. 1969 Total earnings by source, Wyoming vs. the U.S. (thousand 1967 dollars)

Source	1969[a] Wyoming	1969[a] United States	% of Total Wyoming	% of Total U.S.
Total earnings	$794,019	$554,911,996	100.0	100.0
Agriculture, forestry, fisheries	66,297	19,571,289	8.4	3.5
Mining	103,294	5,770,573	13.0	1.0
Contract construction	61,922	34,063,565	7.8	6.2
Manufacturing	54,267	161,427,007	6.8	29.1
Transportation, communications, public utilities	80,929	38,558,070	10.2	6.9
Wholesale & retail trade	117,307	91,115,615	14.8	16.4
Finance, insurance, real estate	27,689	28,932,679	3.5	5.2
Services	97,096	81,704,203	12.2	14.7
Government	185,214	93,838,995	23.3	16.9

(a) Data from 1972 OBERS projections.

Table D-6. Total earnings by source, Campbell county (thousand dollars)

Source[a]	1950	1959	1962	1968	1970	1971
Total earnings	7,604	12,363	13,648	23,206	37,621	32,682
Farm earnings	4,497	6,415	5,911	3,800	4,741	5,282
Manufacturing	(b)	(b)	(b)	(b)	172	224
Mining	73	1,526	1,749	6,269	10,894	8,063
Contract construction	495	408	609	2,138	4,938	2,921
Transportation, communication and public utilities	218	279	470	2,140	4,185	3,431
Wholesale, retail trade	1,314	1,729	2,333	3,884	6,139	5,863
Finance, insurance, real estate	109	241	287	455	678	737
Services	388	620	957	2,129	3,156	3,104
Government earnings	466	1,029	1,243	2,066	2,553	2,889
Other	(b)	(b)	(b)	(b)	165	166

(a) Special unpublished report. Regional Economics Information System Bureau of Economic Analysis. U.S. Department of Commerce, Social and Economic Statistics Administration. August, 1973.

(b) Not shown to avoid disclosure of data for individual reporting units

Table D-7. Total earnings by source, Converse county (thousand dollars)

Source[a]	1950	1959	1962	1968	1970	1971
Total earnings	7,286	12,713	13,031	13,284	16,500	22,466
Farm earnings	5,526	4,049	3,552	2,198	3,887	3,315
Manufacturing	584	277	350	(b)	(b)	(b)
Mining	201	579	799	1,024	(b)	(b)
Contract construction	866	2,764	2,018	1,724	1,825	5,028
Transportation, communication, public utilities	300	465	1,463	2,275	2,836	3,556
Wholesale retail trade	1,419	1,751	1,610	1,751	2,063	2,423
Finance, insurance, real estate	175	219	203	(b)	(b)	454
Services	526	1,142	1,198	1,388	1,999	2,068
Government earnings	671	1,423	1,742	2,380	2,763	3,043
Other	8	44	96	98	147	153

(a) Special unpublished report. Regional Economics Information System, Bureau of Economic Analysis. U.S. Department of Commerce, Social and Economic Statistics Administration. August, 1973.

(b) Not shown to avoid disclosure of data for individual reporting units.

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2. Employment, Tables D-8 and D-9

Tables D-8 and D-9 contain data from the Wyoming Employment Security Commission[1] and *County Business Patterns*[2] for the selected years 1960, 1965, 1969, 1970, 1971, and 1972.

The Wyoming Employment Security Commission figures are yearly averages and are given for "Total Work Force", Non-Covered Employement and Total Manufacturing, and non-Manufacturing categories.

Non-Manufacturing figures are taken from the *County Business Patterns* and are for mid-March only. Thus, because of the difference, calculations for employment in the Non-Manufacturing sub-classes do not add to the yearly total.

1 Unpublished report. Annual employment averages for selected years 1960, 1965, 1969, 1970, 1971. Employment Security Commission of Wyoming. May, 1973.

2 County business patterns. U.S. Department of Commerce, Social and Economic Statistics Administration. Bureau of the Census for 1960, 1965, 1969, 1970, 1971, 1972.

Table D-8. Total work force by employment category, Campbell County

Employment category	1960	1965	1969	1970	1971	1972
Total work force[(a)]	2450	3220	5380	5630	4850	
Unemployed	80	110	140	170	200	
Unemployment rate (%)	3.3%	3.3%	2.6%	3.0%	4.2%	
Covered employment	830	1430	3380	3570	2890	
Manufacturing[(a)]	15	25	30	30	30	30
Non-Manufacturing[(a),(b)]	825	1405	3350	3540	2860	
Agricultural services	5	5	6	10	7	7
Mining	61	441	1039	1386	881	1079
Contract construction	37	65	282	188	115	200
Transportation and other public utilities	37	84	285	333	215	232
Wholesale trade	47	101	174	193	124	173
Retail trade	244	397	694	766	718	672
Finance, insurance, real estate	26	41	66	83	76	81
Services	112	219	405	444	447	414
Other	0	5	16	23	30	6
Non-covered employment[(a)]	1530	1680	1860	1890	1760	
Non-agricultural	640	960	1240	1270	1160	
Non-profit institutions	10	10	60	60	60	
Domestic	50	90	110	120	100	
Self-employed and unpaid unpaid family	240	460	620	640	540	
Federal government	40	40	40	40	40	
Railroads	20	10	10	10	10	
States and local governments	280	350	400	400	410	
Agricultural	890	720	620	620	600	
Wage and salary workers	170	140	110	120	110	
Self-employed and unpaid family	720	580	510	500	490	

(a) Figures are yearly average.

(b) Figures are Mid-March employment.

Table D-9. Total work force by employment category, Converse County

Employment category	1960	1965	1969	1970	1971	1972
Total work force[(a)]	2980	2770	2560	2600	3070	
Employed	80	90	50	110	100	
Unemployment rate (%)	3.0%	3.2%	2.0%	4.2%	3.3%	
Covered employment	1270	1030	1100	1090	1470	
Manufacturing[(a)]	30	50	30	20	20	20
Non-manufacturing[(a),(b)]	1240	980	1070	1070	1450	
Agricultural services	-	3	3	3	3	3
Mining	42	147	136	148	275	292
Contract construction	198	137	119	168	344	104
Transportation & other public utilities	53	182	226	249	278	315
Wholesale trade	14	32	45	24	219	66
Retail trade	266	244	227	269	293	296
Finance, insurance, real estate	28	34	44	48	44	52
Services	130	128	97	119	117	129
Other	13	13	10	20	7	5
Non-covered employment[(a)]	1630	1650	1410	1400	1500	
Non-agricultural	870	1020	880	870	990	
Non-profit institutions	30	30	10	10	10	
Domestic	70	70	50	50	60	
Self-employed & unpaid family	380	440	300	290	370	
Federal government	40	70	50	50	60	
Railroads	30	10	10	10	10	
State & local govts.	320	400	460	460	480	
Agricultural	760	630	530	530	510	
Wage & salary workers	280	240	190	190	180	
Self-employed & unpaid family	480	390	340	340	330	

(a) Yearly average

(b) Mid-March employment.

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3. Occupation Groups of Employed Persons, Tables D-10 and D-11

Contained in tables D-10 and D-11 are data taken from the 1970 Census, General Social and Economic Characteristics, Wyoming.[1] Detailed descriptions of job categories can be found at the end of this census report.

4. Earnings and Income Distribution, Tables D-12 and D-13

Tables D-12 and D-13[2] contain data for Campbell and Converse Counties detailing earnings and income distribution. There are three tables presented for each county: Income of Families and Unrelated Individuals; Type of Income of Families; and Median Earnings in 1969 of Persons in Experienced Civilian Labor Force for Selected Occupation Groups. Definition of terms and other detailed earnings and income distribution can be found in the 1970 Census Report.

1 1970 census of population, general social and economic characteristics, Wyoming. U.S. Department of Commerce, Bureau of the Census. November, 1971.

2 Unpublished report. Annual employment averages for selected years 1960, 1965, 1969, 1970, 1971. Employment Security Commission of Wyoming. May, 1973.

Table D-10. Occupation groups of employed persons, Campbell County

Occupation groups	Number[a]	Percent
Total employed 16 years and over	4,803	100
Professional, technical and kindred workers	448	9.3
Managers and administrators, except farms	471	9.8
Sales workers	262	5.5
Clerical and kindred workers	462	9.6
Craftsmen, foremen, and kindred workers	731	15.2
Operatives, except transport	905	18.8
Transport equipment operatives	443	9.2
Labor except farm	144	3.0
Farmers and farm managers	432	9.0
Farm laborers and farm foremen	135	2.8
Service workers, except private household	356	7.4
Private household workers	24	0.5
Occupation group – female		
Professional, technical & kindred workers	202	
Managers & administrators, except farm	99	
Sales workers	104	
Clerical and kindred workers	401	
Operatives, except transportation	37	
Transport equipment operatives	30	
Laborers, except farm	10	
Farmers and farm managers	22	
Farm laborers and farm foremen	32	
Service workers except private households	225	
Private household workers	24	

(a) The census figures differ from the State Employment Security Commission figures. The difference is due to the fact that census figures represent only one point of time in a year, while the E.S.C. figures are yearly averages.

Table D-11. Occupation groups of employed persons, Converse County

Occupation group	Number[a]	Percent
Total employed 16 years and over	1,596	100
Professional, technical & kindred workers	220	13.8
Managers & administrators, except farm	260	16.3
Sales workers	93	5.8
Clerical and kindred workers	238	14.9
Craftsmen, foremen & kindred workers	314	19.7
Operatives, except transportation	161	10.1
Transport equipment operatives	63	3.9
Laborers, except farm	93	6.0
Farmers and farm managers	206	12.9
Farm laborers and farm foremen	241	15.1
Service workers except private households	246	15.4
Private household workers	25	1.6
Occupation groups – female		
Professional, technical & kindred workers	89	
Managers & administrators, except farm	73	
Sales workers	44	
Clerical and kindred workers	203	
Craftsmen, foremen & kindred workers	11	
Operatives, except transportation	5	
Transport equipment operatives	11	
Laborers, except farm	4	
Farmers and farm managers	17	
Farm laborers and farm foremen	15	
Service workers except private households	155	
Private household workers	25	

(a) See table D-10

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Table D-12. Earnings and income distribution, Campbell County

Income of families and unrelated individuals	$/year
All families	3,085
Less than $1,000	53
$1,000 to $1,999	33
$2,000 to $2,999	61
$3,000 to $3,999	84
$4,000 to $4,999	83
$5,000 to $5,999	132
$6,000 to $6,999	181
$7,000 to $7,999	119
$8,000 to $8,999	221
$9,000 to $9,999	249
$10,000 to $11,999	501
$12,000 to $14,999	560
$15,000 to $24,999	610
$25,000 to $49,999	150
$50,000 or more	48
Median income	$11,303
Mean income	$12,949
Families with female head	114
Mean income	$ 6,615
All families and unrelated individuals	4,002
Median income	$ 9,993
Mean income	$11,405
All unrelated individuals	917
Median income	$ 4,002
Mean income	$ 6,210
Female unrelated individuals	327
Mean income	$ 4,321
Per capita income of persons	$ 3,534
Type of income of families	
All families	3,085
With wage or salary income	2,644
Mean wage or salary income	$10,087
With nonfarm self-employment income	618
Mean nonfarm self-employment income	$ 7,228
With social security income	312
Mean social security income	$ 1,849
With public assistance or public welfare income	33
Mean public assistance or public welfare income	$ 629
With other income	816
Mean other income	$ 2,549
Median earnings in 1969 of persons in experienced civilian labor force for selected occupation groups	
Male, 16 years old and over with earnings	$ 9,048
Professional, managerial, and kindred workers	11,444
Craftsmen, foremen, and kindred workers	10,045
Operatives, including transport	8,818
Laborers, except farm	5,545
Farmers and farm managers	9,333
Farm laborers, except unpaid, and farm foremen	4,017
Female, 16 years old and over with earnings	$ 2,977
Clerical and kindred workers	2,658
Operatives, including transport	1,577

Table D-13. Earnings income distribution 1970, Converse County

Income of families and unrelated individuals	$/year
All families	$ 1,582
Less than $1,000	47
$1,000 to $1,999	62
$2,000 to $2,999	87
$3,000 to $3,999	119
$4,000 to $4,999	58
$5,000 to $5,999	91
$6,000 to $6,999	83
$7,000 to $7,999	136
$8,000 to $8,999	114
$9,000 to $9,999	99
$10,000 to $11,999	290
$12,000 to $14,999	236
$15,000 to $24,999	132
$25,000 to $49,999	28
$50,000 or more	–
Median income	$ 8,947
Mean income	$ 9,191
Families with female head	$ 5,678
Mean income	$ 2,031
All families and unrelated individuals	2,031
Median income	$ 7,507
Mean income	$ 7,917
All unrelated individuals	449
Median income	$ 2,010
Mean income	$ 3,427
Female unrelated individuals	257
Mean income	$ 3,118
Per capita income of persons	$ 2,709
Type of income of families	
All families	1,582
With wage or salary income	$ 1,238
Mean wage or salary income	$ 7,753
With nonfarm self-employment income	345
Mean nonfarm self-employment income	$ 6,334
With farm self-employment income	229
Mean self-farm income	$ 6,421
With social security income	319
Mean social security income	$ 1,556
With public assistance or public welfare income	27
Mean public assistance or public welfare income	$ 1,100
With other income	602
Mean other income	$ 1,264
Median earnings in 1969 of persons in experienced civilian labor force for selected occupation groups	
Male, 16 years old and over with earnings	$ 7,197
Professional, managerial, and kindred workers	$ 9,053
Craftsmen, foremen, and kindred workers	$ 9,345
Operatives, including transport	$ 9,387
Laborers, except farm	$ 4,867
Farmers and farm managers	$ 5,815
Farm laborers, except unpaid, and farm foremen	$ 3,329
Female, 16 years old and over with earnings	$ 2,270
Clerical and kindred workers	$ 2,927
Operatives, including transport	$ –

5. Coal Development Projections Figures D-1 Through D-8

The Wyoming Department of Economic Planning and Development, in its 1974 survey of industry, compiled data related to future development expected for the Powder River Basin. Included in that survey are summaries of construction and permanent employee projections for Converse and Campbell Counties. These projections, showing both expected number and location of labor forces, are presented in figures D-1 through D-4.

Also included in the DEPAD survey are projected expansion and development costs for each county; these are shown in figures D-5 and D-6.

Figures D-7 and D-8 show similar DEPAD projections of water requirements in the two counties during the period 1975 to 1985.

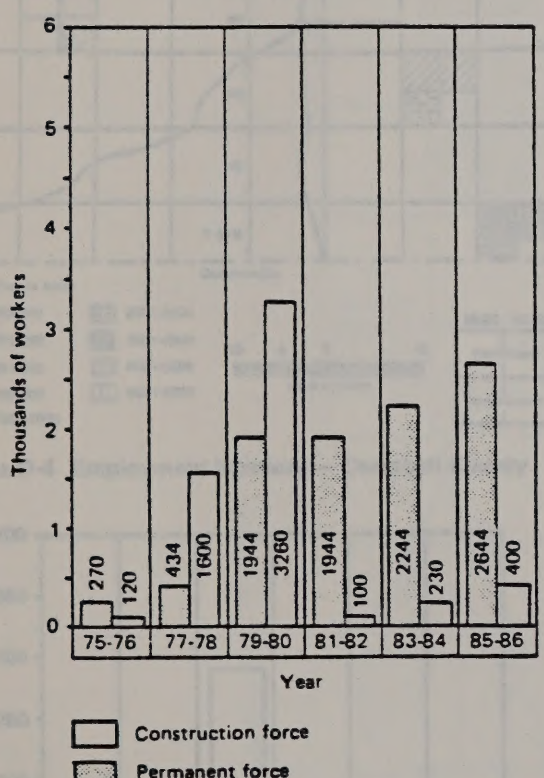

Figure D-1 Permanent and construction employment projections, Converse County

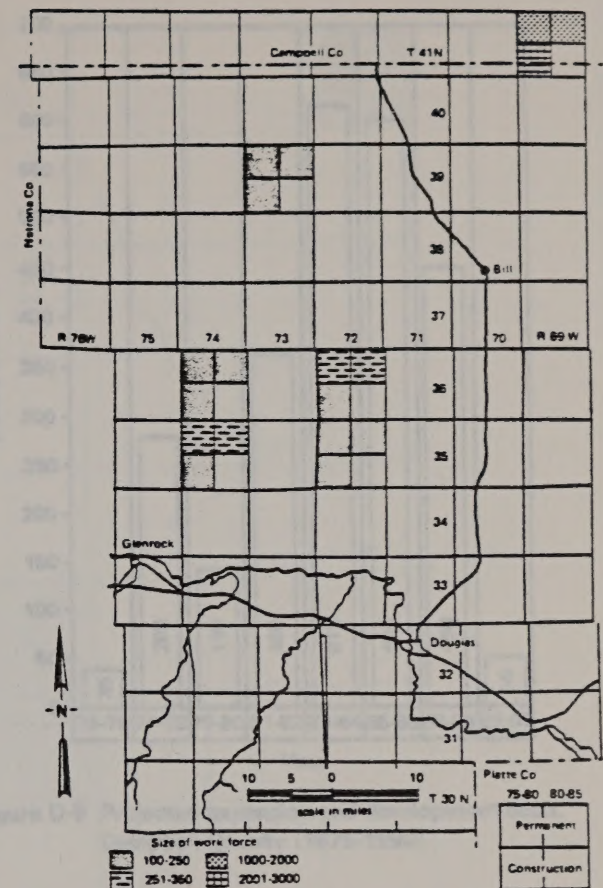

Figure D-2 Employment locations – Converse County

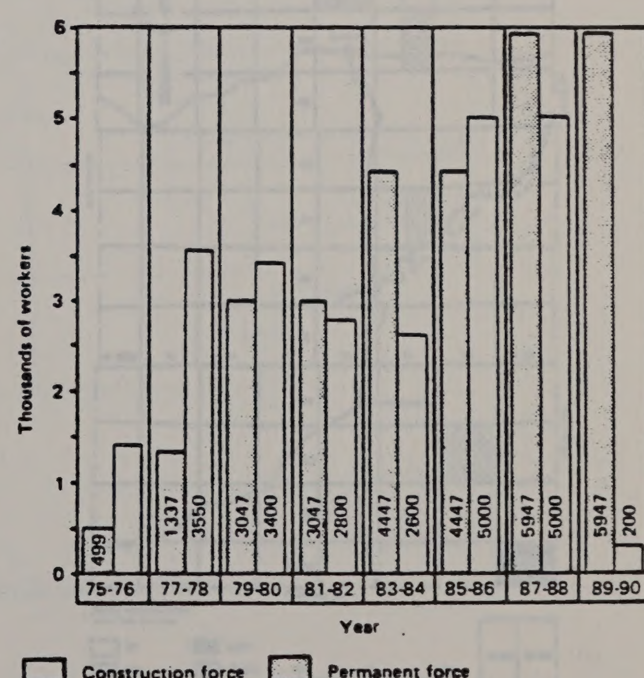

Figure D-3 Permanent and construction employment projections, Campbell County

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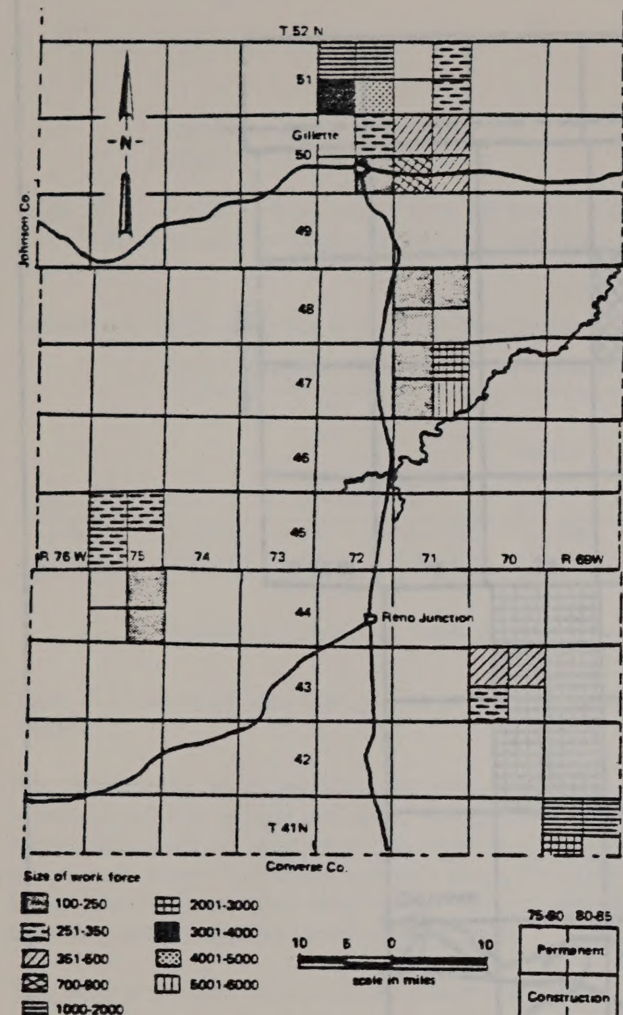

Figure D-4 Employment locations — Campbell County

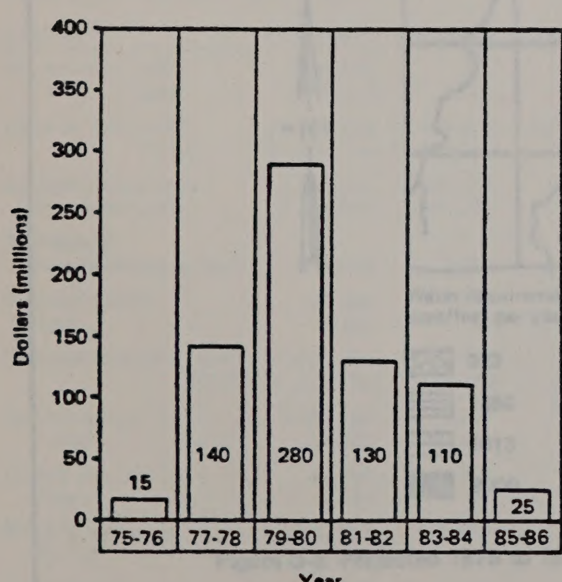

Figure D-5 Projected expansion and development costs, Converse County (1975-1986)

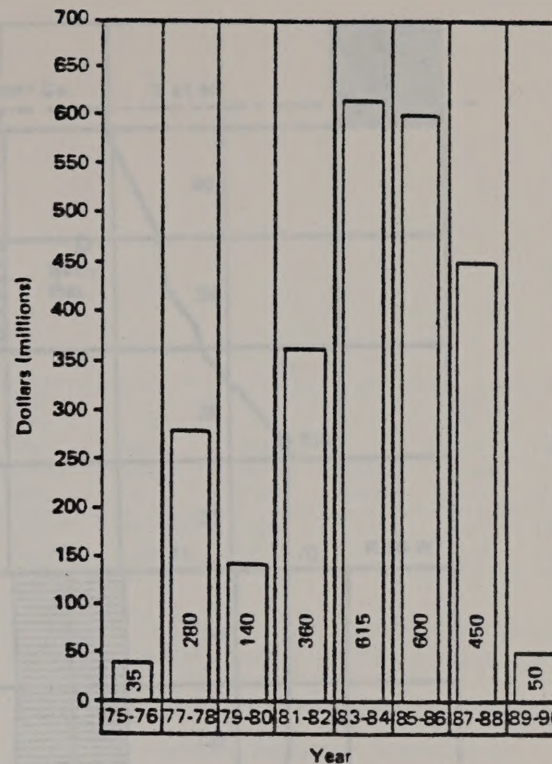

Figure D-6 Projected expansion and development costs, Campbell County (1975-1990)

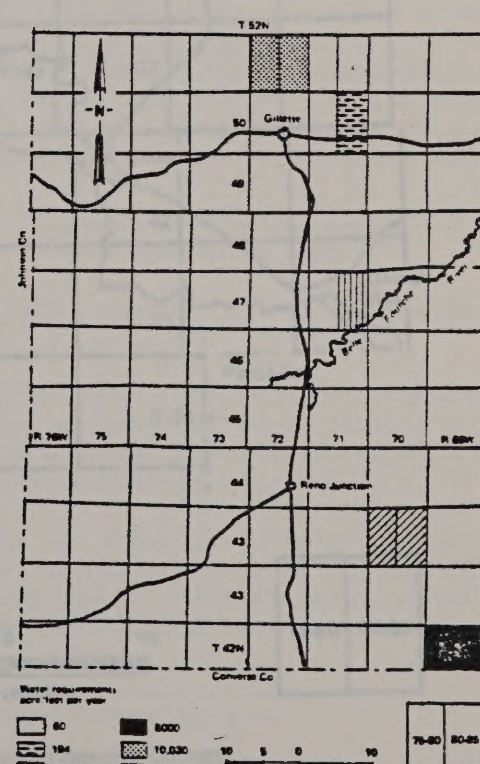

Figure D-7 Projected 1975 to 1985 water requirements, Campbell County

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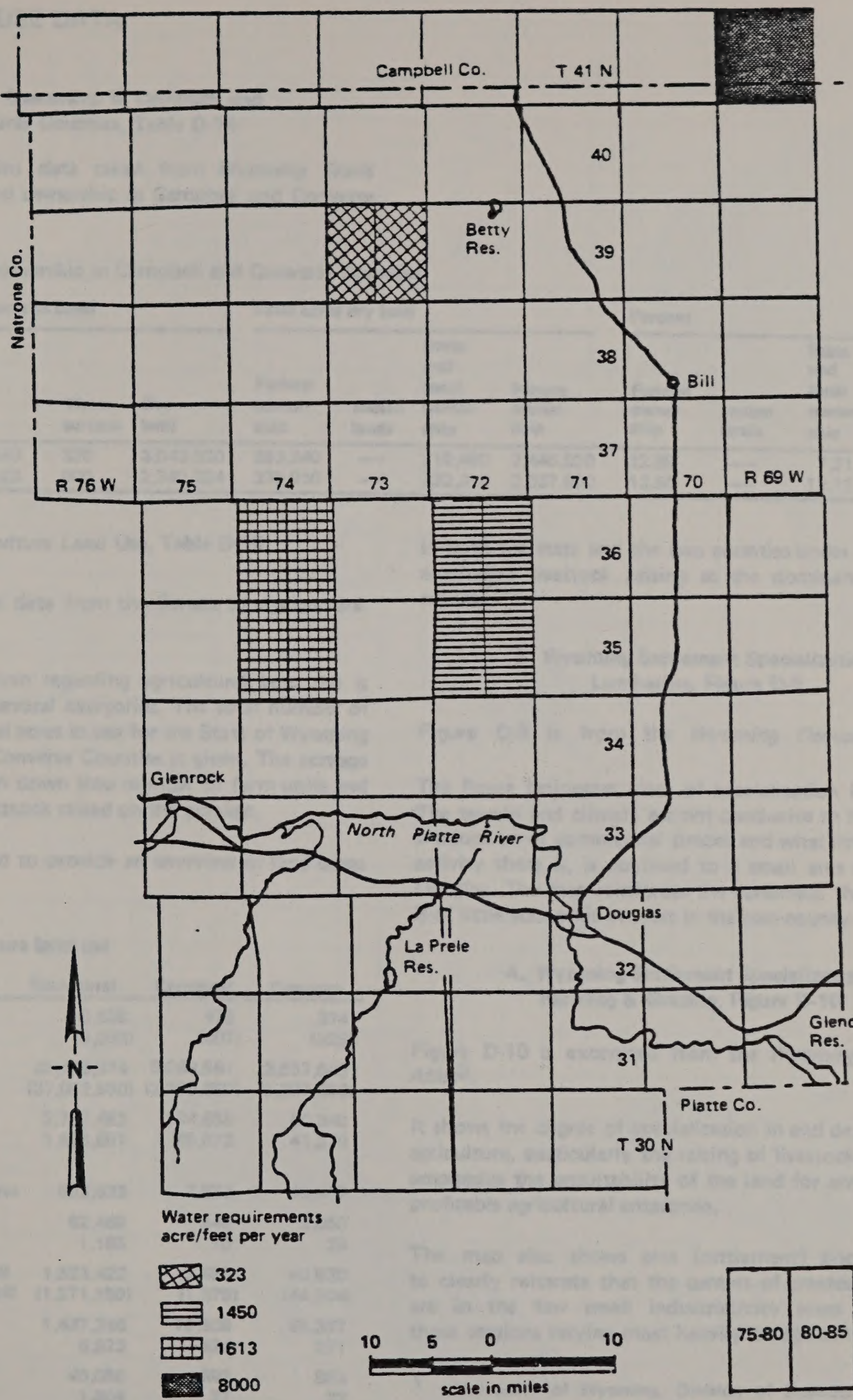

Figure D-8 Projected 1975 to 1985 water requirements, Converse County

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C. RESOURCE USE DATA

1. Land Ownership in Campbell and Converse Counties, Table D-14

Table D-14 contains data taken from *Wyoming Trade Winds*[1] showing land ownership in Campbell and Converse counties.

Table D-14. Land ownership in Campbell and Converse Counties

	Total area in acres			Total acres dry land				Percent			
County	Total	Water surface	Dry land	Federal owner-ship	Indian lands	State and local owner-ship	Private owner-ship	Federal owner-ship	Indian lands	State and local owner-ship	Private owner-ship
Campbell	3,043,840	320	3,043,520	383,240	---	219,460	2,440,820	12.59	---	7.21	80.20
Converse	2,741,120	900	2,740,224	370,010	---	332,310	2,037,900	13.50	---	12.13	74.37

2. Agriculture Land Use, Table D-15

Table D-15 contains data from the *Census of Agriculture*. 1969[2].

The information given regarding agricultural land use is broken down into several categories. The total number of farms and agricultural acres in use for the State of Wyoming and Campbell and Converse Counties is given. The acreage in use is then broken down into number of farm units and types of crops or livestock raised on the acreage.

This table is designed to provide an overview of land usage in both the state and the two counties under study, and to emphasize livestock raising as the dominant agricultural activity.

Table D-15. Agriculture land use

Land use	State total	Campbell	Converse
No. of farms 1969	8,838	479	314
(1964)	(9,038)	(407)	(325)
Acres in farms 1969	35,476,374	3,069,561	2,557,645
(1964)	(37,052,500)	(2,950,650)	(2,297,550)
Cropland, total acres	2,788,453	124,659	60,340
Harvested acres	1,685,597	65,073	41,370
Woodland & woodland pasture acres	503,633	7,653	40,477
Field corn, acres	62,469	545	2,050
farm	1,165	19	28
Irrigated land acres 1969	1,523,422	2,480	40,920
(1964)	(1,571,150)	(1,375)	(44,904)
Cattle & calves, no.	1,437,346	78,309	69,327
Farms	6,923	424	271
Hogs & pigs, no.	40,058	693	883
Farms	1,004	27	23
Sheep & lambs, no.	1,946,820	127,409	137,968
Farms	2,466	191	122
Chickens, no.	157,664	4,046	2,817
Farms	1,819	91	78

3. Wyoming Settlement Specialization, Lumbering, Figure D-9

Figure D-9 is from the *Wyoming Occupance Atlas*[3].

The figure delineates areas of specialization in lumbering. The terrain and climate are not conducive to the large-scale production of commercial timber and what little lumbering activity there is, is confined to a small area southwest of Douglas. The map reinforces the statement that lumbering is of little economic interest in the two-county area.

4. Wyoming Settlement Specialization, Farming & Grazing, Figure D-10

Figure D-10 is excerpted from the *Wyoming Occupance Atlas*[3].

It shows the degree of specialization in and dependence on agriculture, particularly the raising of livestock. It serves to emphasize the unsuitability of the land for any large-scale, profitable agricultural enterprise.

The map also shows area (settlement) population size to clearly reiterate that the centers of greatest population are in the few small industrial/city areas and not in those sections relying most heavily on agricultural activity.

1 University of Wyoming, Division of Business & Economic Research. Wyoming Trade Winds.

2 U.S. Department of Commerce, Bureau of the Census. 1969. Census of Agriculture.

3 Brown, Robert H., 1970. Wyoming Occupance Atlas, in cooperation with the Wyoming Department of Economic Planning and Development.

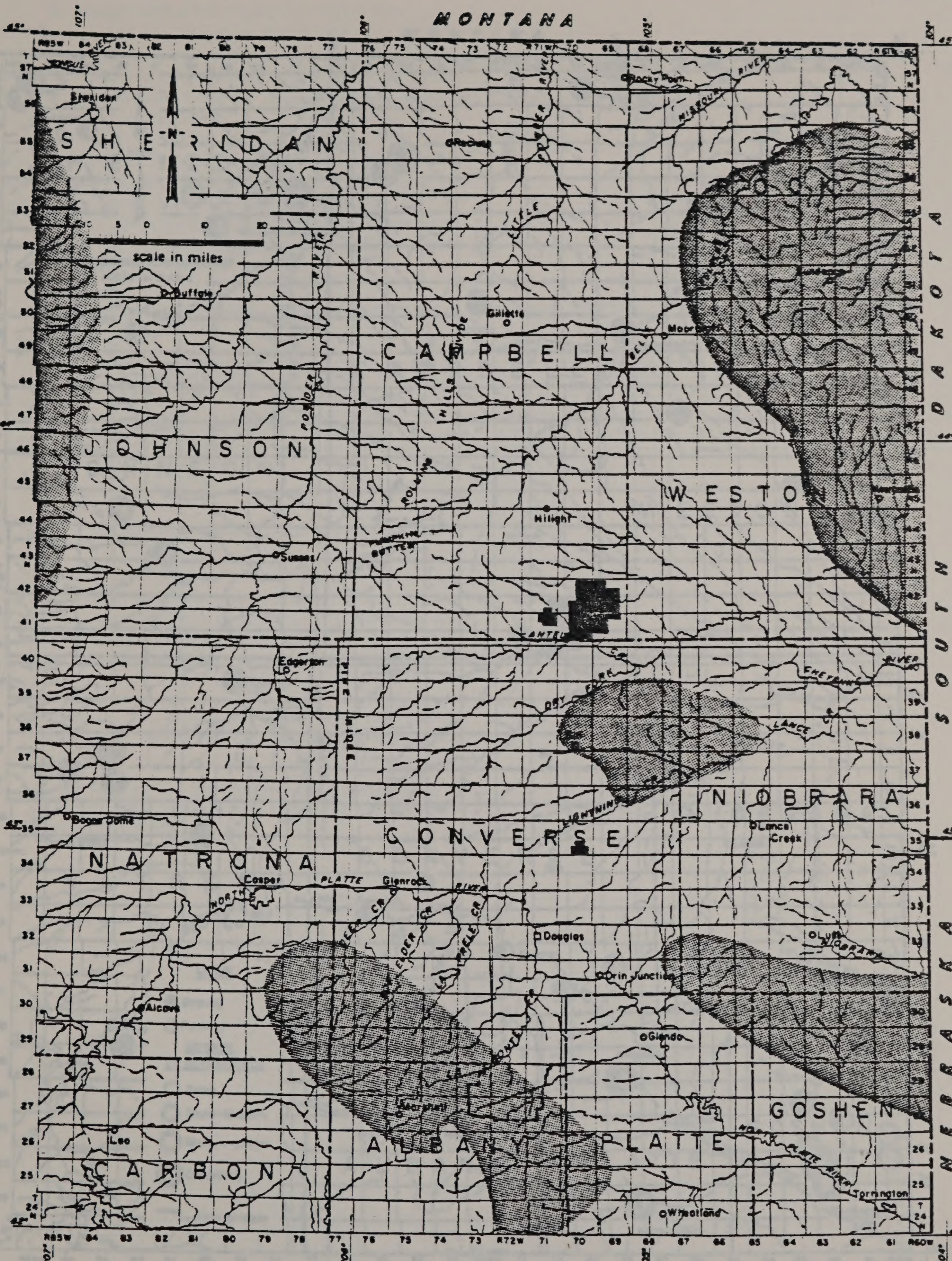

Figure D-9 Wyoming forested areas

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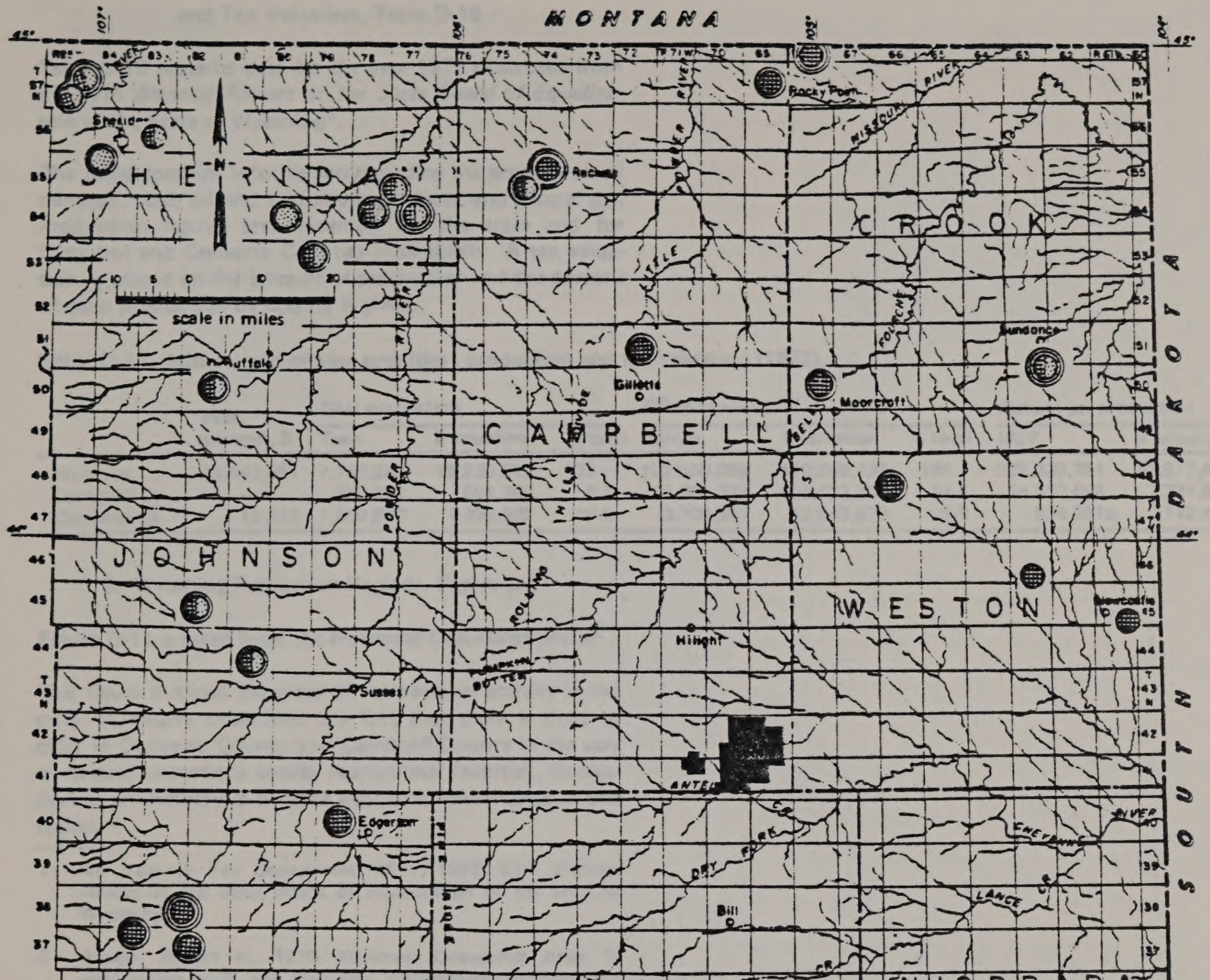

Figure D-10 Wyoming settlement specialization, farming and grazing

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5. Mineral and Mining Activities—Production and Tax Valuation, Table D-16

Table D-16 presents data for the year 1972 excerpted from the *27th Biennial Report of the State Board of Equalization* of the State of Wyoming[1].

The table contains information regarding the production of minerals, coal, oil and petroleum products, and natural gas. Production figures are presented for the state and for Campbell and Converse Counties individually. A tax valuation is placed on the amount of production and the percent of total production by county is given.

Table D-16. Mineral and mining activities - production and tax valuation (1972)

	Misc.	Coal production			Oil production			Natural gas production	
	minerals, $	Tons	$ valuation	% total	Barrels	$ valuation	% total	MCF	$ valuation
Wyoming	46,543,051	7,743,347	15,230,522	100	132,550,059	410,960,436	100	282,320,781	42,917,421
Campbell Co.	--	630,282	598,768	8.1	32,601,523	103,823,200	24.6	54,013,698	7,721,998
Converse Co.	16,282	1,469,923	1,398,932	19.0	3,708,551	12,649,970	2.8	834,381q	112,401

6. Wyoming Recreation Regions, Figure D-11

Figure D-11 is taken from the *Wyoming Occupance Atlas*[2].

This figure outlines the areas of recreational activity in the state. It clearly underlines the fact that there is little to offer in Converse County and Campbell County in the way of natural attractions and/or recreational facilities. Recreation as an industry is of little economic importance in this region.

1 Ad Valorem Tax Department. 1971, 1972, 27th Biennial Report of the State Board of Equalization of the State of Wyoming.

2 Brown, Robert H., 1970. Wyoming Occupance Atlas, in cooperation with the Wyoming Department of Economic Planning and Development.

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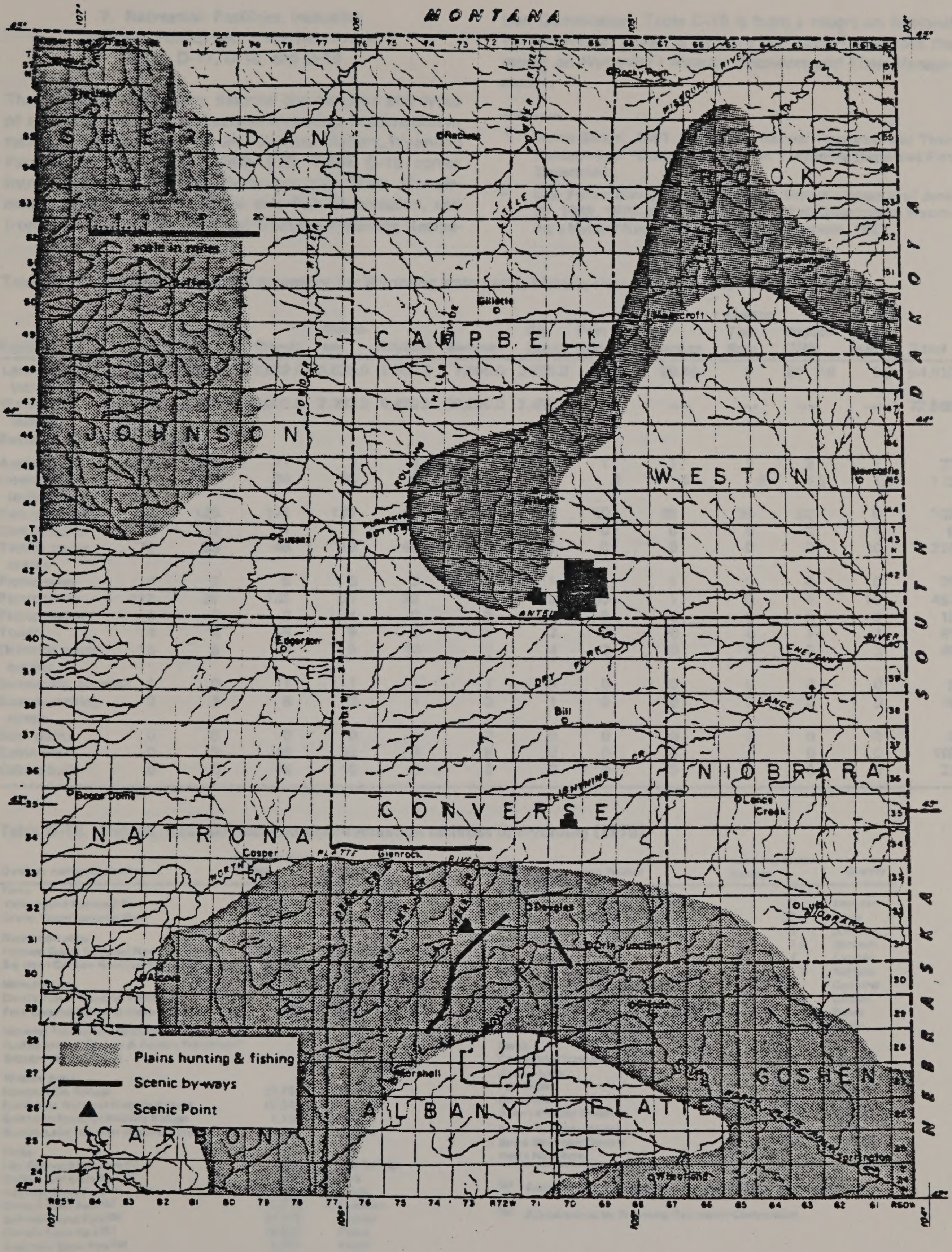

Figure D-11 Wyoming recreation regions

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7. Recreation Facilities, Including National Forests and Wilderness Areas, Tables D-17, D-18, and D-19

The following three tables describe the numbers and types of recreation facilities available in Wyoming. Information in table D-17 comes from the *2nd Biennial Report*, Wyoming Recreation Commission, 1969-1970. Table D-18 comes from *Wyoming's Natural Resources and Their Management*[1] by the Wyoming Game and Fish Commission, and from unpublished data received from the Wyoming Recreation Commission. Table D-19 is from a report on National Forest System Areas as of June 30, 1969,[2] and from the report on *Wyoming's Natural Resources and Their Management*[1].

1 James Simon. 1967. Wyoming's Natural Resources and Their Management. "Outdoor Recreation". Wyoming Game and Fish Department.

2 U.S. Forest Service, National Forest System – areas as of June 30, 1969, 1971. Wyoming Game and Fish Department, Wyoming's Natural Resources and Their Management, 1967.

Table D-17. Recreation facilities inventory for Wyoming state parks, historic sites, and recreation areas (1970)

Facilities	Boysen	Buffalo Bill	Glendo	Guernsey	Keyhole	Seminoe	Big Sandy	Fort Bridger	Fort Fetterman	Oregon Trail Ruts	Register Cliffs	Connor Battle-field	Total
Land area (acres)	22,955.5	3,126.1	3,659.0	5,629.0	5,982.0	1,596.0	3,055.0	37.3	69.46	0	50 .16	5.2	54,010
Water area (acres)	19,660.0	6,690.0	12,000.0	2,382.0	9,420.0	20,050.0	2,488.0	—	—	—	—	—	72,589
Recreation Facilities Inventory													
Access roads	5	5	11	2	3	3	2	1	1	1	2	1	37
Interior roads (miles)	10	16	34	36	6	10	3	.2	.5	.5	1.5	1.0	119
Parking spaces	50	120	175	122	40	60	N/A	60	25	25	50	0	702
Campgrounds	2	2	1	1	1	0	1	0	0	0	0	1	8
Tent & trailer spaces	78	23	46	19	60	0	8	0	0	0	0	10	236
Picnic areas	4	2	5	6	2	2	1	1	1	0	0	0	25
Picnic tables	112	29	135	31	22	9	13	30	1	0	0	10	463
Picnic shelter	4	6	2	4	0	2	0	0	0	0	0	0	18
Toilets	14	6	15	9	9	5	3	2	0	0	1	1	67
Drinking water outlets	14	5	4	5	10	2	4	2	0	0	0	2	49
Swimming, beaches	1	0	1	1	1	1	0	0	0	0	0	0	5
Boat launching ramps	3	2	6	2	1	3	1	0	0	0	0	0	18
Boat docks	0	0	0	0	0	0	0	0	0	0	0	0	0
Cabin sites	0	0	48	52	0	8	0	0	0	0	0	0	108
Cabins built	0	0	16	15	0	2	0	0	0	0	0	0	33

Table D-18. Federal, state and local outdoor-recreation facilities in Wyoming (1970)

Outdoor recreation facility	Land and water acreage	County
Parks		
Yellowstone National Park	2,039,217	Park, Teton
Grand Teton National Park	302,443	Teton
Recreation areas:		
Flaming Gorge National Recreation Area	103,680	Sweetwater
Big Horn Canyon National Recreation Area	60,211	Big Horn
Monuments:		
Devil's Tower National Monument	1,267	Crook
Fort Laramie National Historic Site	192	Goshen
National Forests and Wilderness Areas: (Listed under "Forests & Forests Protection" Section see page 153)		
Wildlife areas:		
National Elk Refuge	23,790	Teton
Pathfinder National Wildlife Refuge	46,341	Carbon
Bamforth National Wildlife Refuge	1,166	Albany
Button Lake National Wildlife Refuge	1,968	Albany
Parks:		
Hot Springs State Park[a]	640	Hot Springs
Buffalo Bill State Park[b]	11,816	Park
Keyhole State Park[b]	15,402	Crook
Boysen State Park[b]	42,616	Fremont
Seminoe State Park[b]	21,619	Carbon
Glendo State Park[b]	15,659	Platte
Guernsey State Park[b]	8,011	Platte
Big Sandy State Park[b]	5,503	Fremont

Outdoor recreation facility	Land and Water Acreage	County
Historic monuments:		
Connor Battle Field State Park[b]	5	Sheridan
Fort Bridger State Park[b]	37	Uinta
Fort Phil Kearney Historic Site	3	Johnson
Fort Reno Historic Site	1.4	Johnson
Names Hill Historic Site	4	Lincoln
Red Buttes Battlefield	.7	Natrona
Fort Fetterman Historic Site[b]	60	Converse
Platte River Crossing	.8	Carbon
Register Cliff[b]	.2	Platte
Oregon Trail Ruts[a]	--	Platte
Parks:		
Casper Mountain Park	480	Natrona
Alcova Lake	6,120	Natrona
Pathfinder	N/A	Natrona
Gray Reef	N/A	Natrona
Ayer's Natural Bridge	14	Converse
Scientific monuments:	210	Park
Spirit Mountain Davern	320	Natrona
Hell's Half Acre		

(a) Administered by Wyoming State Board of Charities and Reform

(b) Administered by Wyoming Recreation Commission.

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Table D-19. National forests in Wyoming, including wilderness and primitive areas within forests (1969)

National Forest and Wilderness Area	Gross area within boundaries acres	Net area administered by Forest Service acres	Other lands within boundaries acres	County
Ashley National Forest(d)	101,063	91,149	9,914	Sweetwater
Bighorn National Forest	2,121,713	1,113,769	7,944	Big Horn, Johnson, Sheridan
Black Hills National Forest(a)	199,467	172,443	27,024	Washakie
Bridger National Forest(d)	1,340,005	1,328,419	11,486	Crook, Weston Fremont, Lincoln, Sublette
Caribou National Forest(a),(d)	383,300	383,300	—	Teton, Lincoln
Medicine Bow National Forest	1,401,943	1,092,364	309,579	Albany, Carbon, Converse Natrona, Platte
Shoshone National Forest(b)	2,463,603	2,430,626	32,977	Fremont, Hot Springs, Park Sublette, Teton
Targhee National Forest(a)(d)	9,569	7,868	1,701	Lincoln, Teton
Teton National Forest(d)	332,529	338,108	2,421	Teton, Fremont, Lincoln, Park
Wasatch National Forest(d)	1,152,622	1,124,433	28,189	Uinta
Thunder Basin National Grassland(c),(d)	572,315	572,315	—	Campbell, Converse, Niobrara, Weston
Bridger Wilderness Area (Bridger National Forest)	563,500	563,500	—	Sublette
Cloud Peak Primitive Area (Bighorn National Forest)	137,000	137,000	—	Johnson
Glacier Wilderness Area (Shoshone National Forest)	177,000	177,000	—	Fremont
North Absaroka Wilderness Area (Shoshone National Forest)	351,104	351,104	—	Park
Popo Agie Primitive Area (Shoshone National Forest)	70,000	70,000	—	Fremont
South Absaroka Wilderness Area (Shoshone National Forest)	483,678	483,130	548	Park
Stratified Wilderness Area (Shoshone National Forest)	203,930	203,930	—	Fremont
Teton Wilderness Area (Shoshone National Forest)	47,704	37,462	9,942	Fremont, Park, Teton
	—	—	—	
Total	10,538,730	9,677,920	441,825	

(a) Black Hills, Caribou, Targhee, and Wasatch National Forests are only partially contained within Wyoming boundaries. Areas shown for these forests in acreage within the state.

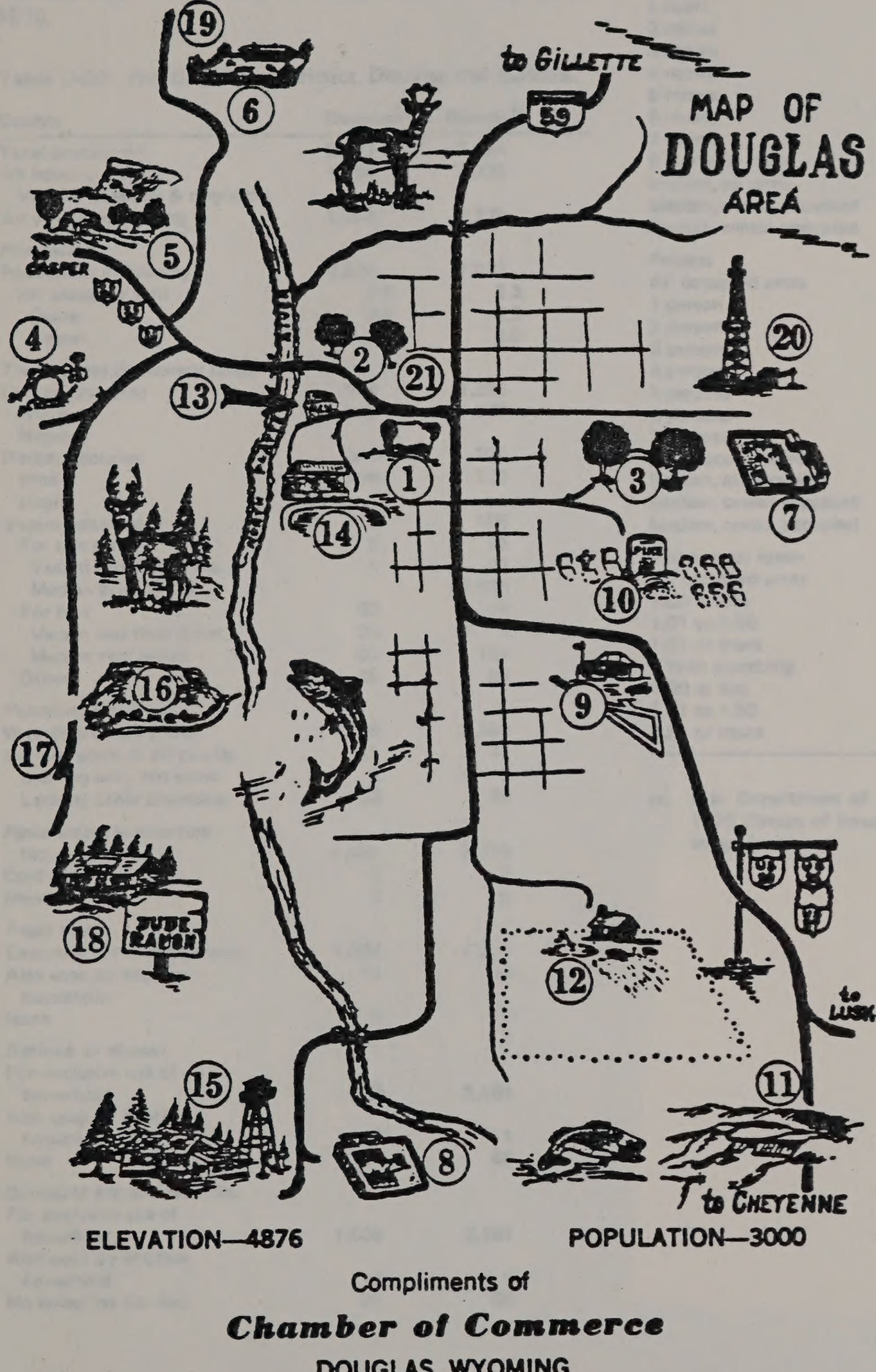
(b) Shoshone National Forest was the first national forest established in the United States — March 30, 1871.

(c) Thunder Basin National Grassland administered by Medicine Bow National Forest.

(d) Current 1970 Figures, all others are the 1969 figures.

8. City of Douglas—Cultural & Recreational Sites, Figure D-12

The map shown in figure D-12, provided by the Chamber of Commerce, Douglas, Wyoming, details the cultural and recreational areas near and in Douglas and gives the relative locations to the town.



(1) Howdy Wagon
Chamber of Commerce information.
(2) Riverside Trailer Park
Free overnight camping in the trees by the Platte River Bridge.
(3) Washington Park
Picnic facilities; in East Douglas.
(4) Public Fishing Lake
West of Douglas 5 miles.
(5) Natural Bridge
Picnic facilities west of Douglas 14 miles, off Highway U. S. 20-87-I-25.
(6) Fort Fetterman
Site of historic "old west" Fort 10 miles northwest of Douglas.
(7) Douglas Municipal Pool
Free swimming for school age children from 1 to 5 p.m.
(8) Jackalope Plunge
Water from natural warm spring. Restaurant and picnic area, 6 miles south of Douglas.
(9) Municipal Airport
5,000-foot asphalt runway. In southeast Douglas.
(10) George Pike's Grave
Notorious outlaw's grave, Douglas cemetery.
(11) Glendo Dam & Reservoir
87 miles shore line - good trout fishing. 28 miles southeast of Douglas.
(12) Douglas Golf Course
Grass greens - 9 holes - club house.
(13) Wyoming Pioneer Memorial Museum
Historic "old west" - at Wyoming State Fair Grounds.
(14) Wyo. State Fair Grounds
Site of Wyoming State Fair—5 big days—last week in August.
(15) Esterbrook Hunting Lodge
Scenic lodge - meals - lodging - 26 miles south of Douglas.
(16) Moss Agate Hill
Rock hunting by permission of owner. 19 miles southwest of Douglas.
(17) Cold Springs
Scenic drive - pine trees - cold springs - Ranger Station - 40 miles southwest of Douglas.
(18) Silver Spruce Lodge
Horseback riding - fishing - meals and lodging on reservations. 55 miles southwest of Douglas.
(19) Uranium Mines
37 miles northwest of Douglas.
(20) "Flat Top" Oil Field
17 miles northeast of Douglas.
(21) Jackalope Statue
Located in downtown Douglas.

Figure D-12 City of Douglas — cultural and recreational sites

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D. HOUSING CHARACTERISTICS, DOUGLAS AND GILLETTE, TABLE D-20

Table D-20 gives occupancy, utilization and plumbing characteristics for housing in Douglas and Gillette as of 1970.

Table D-20. Housing characteristics, Douglas and Gillette.

County	Douglas[a]	Gillette[a]
Total population	2,677	7,194
All housing units	1,066	2,220
Vacant—seasonal & migratory		
All yr.-round housing	1,066	2,228
Population		
Population in housing	2,626	7,038
Per occupied unit	2.8	3.3
Owner	2.8	3.5
Renter	2.7	3.0
Tenure, race & vacancy status		
Owner, occupied	645	1,385
White	642	1,379
Negro		
Renter occupied	306	735
White	304	722
Negro		
Vacant year-round	115	108
For sale only	6	28
Vacant less than 6 mo.	4	27
Median price asked		23,000
For rent	63	18
Vacant less than 2 mo.	25	6
Median rent asked $	60	124
Other	46	62
Plumbing facilities		
With all plumbing facil.	1,036	2,184
Lacking some or all plumb.	15	44
Lacking only hot water	2	5
Lacking other plumbing	26	39
Piped water in structure		
Hot & cold	1,058	2,210
Cold only	5	9
None	3	9
Flush toilet		
Exclusive use of household	1,046	2,201
Also used by another household	15	16
None	5	11
Bathtub or shower		
For exclusive use of household	1,038	2,161
Also used by another household	3	1
None	25	66
Complete kitchen facilities		
For exclusive use of household	1,038	2,161
Also used by another household	3	1
No complete kit. fac.	25	66
Units in structure		
1	795	1,139
2 or more	197	444
Mobile home or trailer	74	645
Rooms		
1 room	19	65
2 rooms	65	90
3 rooms	132	283
4 rooms	268	647
5 rooms	249	660
6 rooms	136	211
7 rooms	90	121
8 rooms or more	107	151
Median, all units	4.7	4.5
Median, owner occupied	5.1	4.9
Median, renter occupied	4.0	3.8
Persons		
All occupied units	951	2,120
1 person	251	312
2 persons	283	550
3 persons	131	342
4 persons	128	380
5 persons	82	287
6 persons	49	153
7 persons	17	56
8 persons or more	10	40
Median, all occupied	2.3	3.1
Median, owner occupied	2.3	3.4
Median, renter occupied	2.3	2.5
Persons per room		
All occupied units	951	2,120
1.00 or less	888	1,835
1.01 to 1.50	48	210
1.51 or more	15	75
With plumbing	922	2,078
1.00 or less	831	1,796
1.01 to 1.50	47	209
1.51 or more	14	73

(a) U.S. Department of Commerce, Bureau of the Census. 1971. 1970 Census of housing, general housing characteristics, Wyoming. June.

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